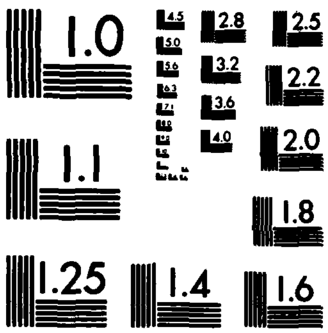
AD-A127 294 EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION 1/4
(U) KEARNEY (A T) INC CHICAGO ILL J EGAN ET AL. SEP 81
DACW72-79-C-0003

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12

National Waterways Study

FINAL REPORT

EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION

PREPARED FOR THE

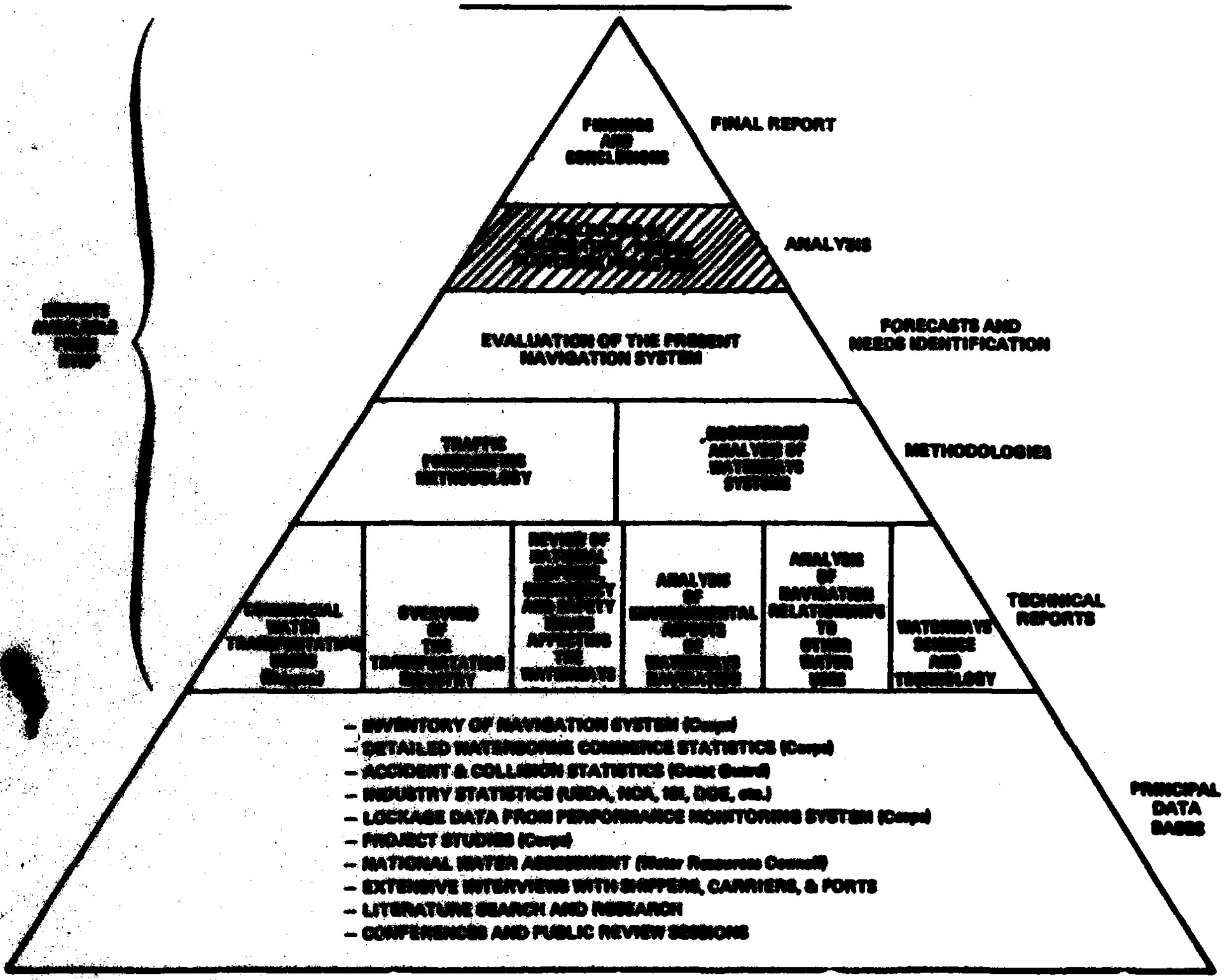
U.S. ARMY CORPS OF ENGINEERS
INSTITUTE FOR WATER RESOURCES
WATER RESOURCES SUPPORT CENTER
KINGMAN BUILDING
FORT BELVOIR, VIRGINIA

UNDER CONTRACT NUMBER

DACW 72-79-C-0003

MAY 1982

NATIONAL WATERWAYS STUDY
AVAILABLE CONTRACTOR REPORTS



NATIONAL WATERWAYS STUDY

EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION

PREFACE

This report is one of eleven technical reports provided to the Corps of Engineers in support of the National Waterways Study by A. T. Kearney, Inc. and its subcontractors. This set of reports contains all significant findings and conclusions from the contractor effort over more than two years.

A. T. Kearney, Inc. (Management Consultants) was the prime contractor to the Institute for Water Resources of the United States Army Corps of Engineers for the National Waterways Study. Kearney was supported by two subcontractors: Data Resources, Inc. (economics and forecasting) and Louis Berger & Associates (waterway and environmental engineering).

The purpose of the contractor effort has been to professionally and evenhandedly analyze potential alternative strategies for the management of the nation's waterways through the year 2000. The purpose of the National Waterways Study is to provide the basis for policy recommendations by the Secretary of the Army and for the formulation of national waterways policy by Congress.

This report forms part of the base of technical research conducted for this study. The purpose of this report was to identify and evaluate action strategies to meet water transportation identified in the report, Evaluation of the Present Navigation System. The results of this analysis were reviewed at public meetings held throughout the country. Comments and suggestions from the public were incorporated.

This is a deliverable under Contract DACW 72-79-C-0003. It represents the output to satisfy the requirements for the deliverable in the Statement of Work. This report constitutes the single requirement of this Project Element, completed by A. T. Kearney, Inc. and its primary subcontractors, Data Resources, Inc. and Louis Berger and Associates, Inc. The primary technical work on this report was the responsibility of A. T. Kearney, Inc. This document supercedes all deliverable working papers. This report is the sole offical deliverable available for use under this Project Element.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A127294
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) NATIONAL WATERWAYS STUDY Evaluation of Alternatives Future Strategies for Action	5. TYPE OF REPORT & PERIOD COVERED Final Report January 1979 - September 1981
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John Egan David Reitz Edwin Isely A. T. Kearney, Inc.	8. CONTRACT OR GRANT NUMBER(s) DACW 72-79-C-0003
9. PERFORMING ORGANIZATION NAME AND ADDRESS A. T. Kearney, Inc. 222 South Riverside Plaza Chicago, Illinois 60606	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Institute for Water Resources/Corps of Engineers Kingman Building, Telegraph & Leaf Roads Fort Belvoir, Virginia 22060	12. REPORT DATE September, 1981
	13. NUMBER OF PAGES 230
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Analytical Framework of the study, Evaluation Measures, Evaluation Methodology, Strategies for action, Evaluation of Strategies, Sensitivity analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report of the National Waterways Study, Evaluation of Alternative Future Strategies for Action, is one of two key "integration" tasks. Its purposes are to identify and evaluate alternative action strategies for meeting national water transportation needs. Water transportation needs, the subject of the report, Evaluation of the Present Navigation System, have been determined by comparing forecasts of present and projected water transportation use with estimates of the present and future capability of the waterway system. Having determined water transportation needs, action strategies to meet these needs are identified and evaluated in this report, Evaluation of Alternative Future Strategies for Action. This report presents four alternative strategies for action along with various measures designed to evaluate the relative merits or disadvantages of adopting each strategy. It should be emphasized that, as a practical matter, any one of these four strategies are not likely to be adopted in whole. Rather, the strategies have been formulated to represent distinct policy and top management options available to Congress and the Corps for meeting national water transportation

DD 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

National Waterways Study

FINAL REPORT

EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION

TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	
	Study Objectives and Scope	13
	Study Organization	15
	Purpose and Organization of this Report	15
II	ANALYTICAL FRAMEWORK	
	Description of Analytical Framework	29
III	EVALUATION MEASURES AND METHODOLOGY	
	Purpose of Section	34
	Process for Selection of Evaluation Measures	34
	Definition of Evaluation Measures	36
	Criteria for Selection of Evaluation Measures	36
	Other Considerations in Selection of Evaluation Measures	40
	Evaluation Measures Actually Used	41
	Methodologies for Computing Evaluation Measures	42
	Evaluation Measures and Procedures Considered and Rejected	50
	Relationship of Evaluation Measures to Strategies	51
IV	STRATEGIES FOR ACTION	
	Introduction	52
	Purpose of Strategies	52
	Criteria for Design and Selection of Strategies	56
	Description of Strategies	58
	Description and Selection of Actions	61
	Cost of Components of Strategies	82

TABLE OF CONTENTS (cont)

Section	Title	Page
V	EVALUATION OF STRATEGIES	
	Introduction	124
	Evaluation of the Present System	124
	Application of Strategies	125
	National Evaluation	126
	Industry Evaluation	149
	Regional Evaluation	153
	Summary	198
VI	SENSITIVITY ANALYSIS	
	Purpose of Section	206
	High Coal Export Forecast	206
	Defense	207
	Miscellaneous Sensitivities	208
	Sensitivity of Strategy II Classification Scheme	209
VII	CONCLUSIONS	
	Glossary of Terms	214

LIST OF TABLES

Number	Title	Page
IV-1	Strategy Decision Priorities	62
IV-2	Allocation of Corps of Engineers Operations and Maintenance Activities	77
IV-3	Classification Scheme for Shallow Draft Waterways	78
IV-4	Analysis of Dredging on Class B Shallow Draft Segments	80
IV-5	Funding Priorities for Strategy II	82
IV-6	Relative Rates of Change of Selected Price Indices	90
IV-7	Trends in Corps of Engineers Budgets	96
IV-8	Appropriations for Navigation Construction	98
V-1	Projected Use Accommodated by the Present System	127
V-2	Lock Actions Taken by Strategy	129
V-3	Traffic Versus Projected Use in 2003	131
V-4	Annual Growth in Projected Use for 2003	133
V-5	Private Linehaul Costs for Domestic Inland Waterways Traffic in 2003	135
V-6	Reduction in Private Linehaul Costs for Domestic Inland Traffic in 2003 by Strategy	137
V-7	Private Linehaul Costs for Domestic Great Lakes/Seaway Taffic in 2003	138
V-8	Reduction in Private Linehaul Costs for Great Lakes/Seaway Traffic in 2003 by Strategy	138

LIST OF TABLES

Number	Title	Page
V-9	Safety Actions Taken by Strategy from 1985 to 2003	140
V-10	Public Expenditures for Waterways from 1977 to 2003	142
V-11	Public Expenditures for Waterways by Type of Expense from 1977 to 2003	146
V-12	Public Expenditures for Waterways by Type of Waterway from 1977 to 2003	147
V-13	Annual Fuel Tax Revenues in 2003	148
V-14	Percent of Domestic Traffic Handled in 2003	149
V-15	Private Linehaul Costs for Domestic Waterways Traffic by Industry in 2003	152
V-16	Regional Evaluation Report for Upper Mississippi in 2003	155
V-17	Regional Evaluation Report for Lower Upper Mississippi in 2003	152
V-18	Regional Evaluation Report for Lower Mississippi in 2003	161
V-19	Regional Evaluation Report for Baton Rouge to Gulf in 2003	163
V-20	Regional Evaluation Report for Illinois Waterway in 2003	167
V-21	Regional Evaluation Report for Missouri River in 2003	169
V-22	Regional Evaluation Report for Ohio River in 2003	171

LIST OF TABLES

Number	Title	Page
V-23	Regional Evaluation Report for Tennessee River in 2003	175
V-24	Regional Evaluation Report for Arkansas River in 2003	177
V-25	Regional Evaluation Report for Gulf Coast West in 2003	179
V-26	Regional Evaluation Report for Gulf Coast East in 2003	181
V-27	Regional Evaluation Report for Mobile River and Tributaries in 2003	184
V-28	Regional Evaluation Report for South Atlantic Coast in 2003	186
V-29	Regional Evaluation Report for Middle Atlantic Coast in 2003	188
V-30	Regional Evaluation Report for North Atlantic Coast in 2003	189
V-31	Regional Evaluation Report for Great Lakes-St. Lawrence Seaway-New York State Waterways in 2003	190
V-32	Regional Evaluation Report for Washington-Oregon Coast in 2003	192
V-33	Regional Evaluation Report for Columbia-Snake-Willamette Rivers in 2003	193
V-34	Regional Evaluation Report for California Coast in 2003	195
V-35	Regional Evaluation Report for Alaska in 2003	196

LIST OF TABLES

Number	Title	Page
V-36	Regional Evaluation Report for Hawaii in 2003	196
V-37	Regional Evaluation Report for U.S. Caribbean in 2003	197
VI-1	Sensitivity Analysis of Arkansas-Verdigris-White Rivers	201

LIST OF FIGURES

Number	Title	Page
I-A	National Waterways Study Elements	16
II-A	National Waterways Study Final Integration Framework	30
V-A	Annual Public Costs of the Present System from 1977 to 2003	143
V-B	Annual Public Costs of the Present System by Expense Type from 1977 to 2003	144
V-C	Annual Public Costs by Strategy from 1977 to 2003	145

LIST OF EXHIBITS

Number	Title
I-1	NWS Reporting Regions and Analysis Segments
I-2	NWS Reporting and Analysis Commodity Groups
IV-1	Candidate Major Structural Actions to Increase Lock Capacity
IV-2	Candidate Safety Actions for Strategies I-III
IV-3	Candidate Safety Actions for Strategy IV
IV-4	Actions to Improve Linehaul Cost
IV-5	Deferred Maintenance Dredging Included in Strategy IV
IV-6	Obsolete Locks Replaced or Modified Under Strategy IV
IV-7	Minor Ports and Side Channels
IV-8	Projected Dredging Unit Cost Growth Rates
V-1	Lock Actions Taken by Strategy (High Use Scenario)
V-2	Lock Actions Taken by Strategy (Low Use Scenario)
V-3	Lock Actions Taken by Strategy (Bad Energy Scenario)
V-4	Lock Actions Taken by Strategy (High Coal Exports Forecast)
V-5	Lock Actions Taken by Strategy (Defense Forecast)
V-6	Lock Actions Taken by Strategy (Miscellaneous Adjustments Forecast)

TABLE OF CONTENTS

LIST OF APPENDICES

Number	Title
A	Breakdown of Dredge Volumes
B	Breakdown of Other Operations and Maintenance Expenses
C	Environmental Evaluation of Strategy Actions
D	Linehaul Cost Evaluation Methodology for Channel Deepening
E	Environmental Sensitivity Analysis

I - INTRODUCTION

Evaluation of Strategies for Action (Element L) is one of 11 reports prepared by A. T. Kearney, Inc. in association with Data Resources, Inc. and Louis Berger and Associates for the National Waterways Study (NWS). The National Waterways Study is sponsored by the Institute for Water Resources, U.S. Corps of Engineers.

STUDY OBJECTIVES AND SCOPE

The objectives of the contractor's portion of NWS are to:

> IDENTIFY AND ANALYZE ALTERNATIVE STRATEGIES PROVIDING A NAVIGATION SYSTEM TO SERVE THE NATION'S CURRENT AND PROJECTED TRANSPORTATION NEEDS.

For purposes of this study, strategies are defined as alternative sets of policy and top management directives for taking actions to meet water transportation needs. Transportation needs are defined as the changes in the navigation system that would be required to handle current and projected waterborne commodity flows safely and at a marine linehaul cost consistent with the historical cost relationship among transportation modes. The use of the word "needs" is not intended to suggest changes in the navigation system which must be undertaken at any cost.

In requesting the Corps to undertake this study, the Congress is seeking to obtain information on the broad options available to it for meeting the needs of water transportation users through the year 2000. In contrast to a review of isolated projects, Congress is seeking information about the nation's overall navigation system and strategies to improve it.

In order to understand the scope of the NWS, it is necessary to state what the NWS is not. NWS is not a national transportation study. Strategies have neither

been identified nor evaluated with regard to shortfalls in rail, truck, or pipeline capacity, even though, for example, rail transportation bottlenecks can be expected to affect greatly the growth and development of individual coastal ports.

NWS is not a water resource study. The study was designed from the beginning to formulate strategies for meeting water transportation needs. Other uses of water that compete with or complement water transportation use have been discussed in a NWS report entitled Navigation Relationship to Other Water Uses (Element G) and the principal findings of this study have been incorporated into the methodology of this report.

Finally, NWS is neither a detailed plan for Congress and the Corps to implement, nor a project feasibility study. Instead, the NWS is meant to identify and evaluate the basic options available to Congress, the Corps, and other maritime agencies for meeting current and projected water transportation needs.

For purposes of this study, the present waterways system is defined as the currently used waterways system as of December 1978. However, the following commercial navigation projects that are funded for construction or under construction have been included in the present waterways system; Tennessee-Tombigbee Waterway; Red River; 1,200' by 110' lock replacement projects at Lock and Dam 26 on the Mississippi at Alton, Illinois and Vermilion on the Gulf Intracoastal Waterway West; and new locks at two sites on the Ouachita River.

For reporting purposes, the present waterways system has been divided into 22 geographical areas. These 22 areas have, in turn, been divided into 61 segments for analysis purposes. Exhibit I-1 presents a listing of these regions and segments. Waterborne commodity flows are presented for reporting purposes in 14 commodity groups. These 14 groups are, in turn, aggregations of 48 analytical commodities. Exhibit I-2 presents a listing of these commodities.

STUDY ORGANIZATION

In order to meet the NWS objectives, a series of technical analyses and integration steps had to be completed. Figure I-A depicts the NWS workplan and the manner in which the pieces of the study fit together.

As can be seen by this figure, the NWS has been divided into 14 "elements" involving efforts by the contractor, IWR/NWS team and the Corps field organization. Public involvement has been sought throughout the NWS. Element A served primarily as input to Element K1. Elements C, D, E/F, G, and M all provided input at varying levels to the commodity flow projection process of Element B. In addition, Elements D, E/F, K1, G, and M provided input to Element K2, the evaluation of the present waterways system.

PURPOSE AND ORGANIZATION OF THIS REPORT

Element L (Evaluation of Alternative Future Strategies for Action), the subject of this report, is one of two key "integration" tasks. Its purposes are to identify and evaluate alternative action strategies for meeting national water transportation needs.

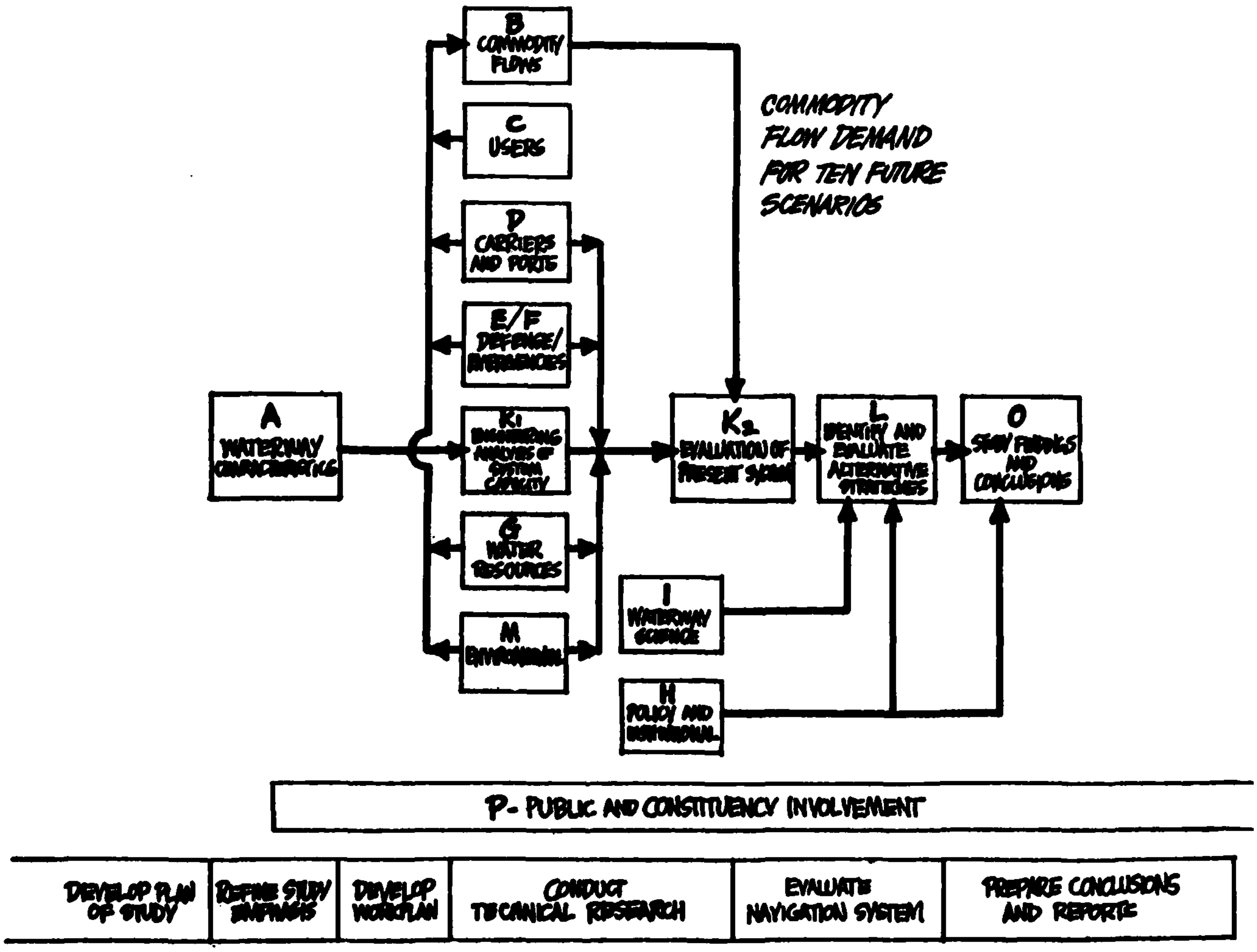
Water transportation needs, the subject of the Element K2 report, have been determined by comparing forecasts of present and projected water transportation use with estimates of the present and future capability of the waterway system.

Having determined water transportation needs, action strategies to meet these needs are identified and evaluated in Element L (Evaluation of Alternative Future Strategies for Action).

This report presents four alternative strategies for action along with various measures designed to evaluate the relative merits or disadvantages of adopting each strategy. It should be emphasized that, as a practical matter, any one of these four strategies is not likely to be adopted in whole. Rather, the strategies have been

Figure I-A

National Waterways Study Elements



formulated to represent distinct policy and top management options available to Congress and the Corps for meeting national water transportation needs.

Public participation was an integral part of the process of formulating and evaluating strategies for action. Public briefings were held on November 13, 18 and 19 during 1980 in Washington, D.C., St. Louis, Missouri, and Portland, Oregon respectively. The purposes of these briefings were to present for public review the preliminary findings of the evaluation of both the present waterway system and the four NWS strategies for action. Public comments were explicitly solicited regarding the type of sensitivity analyses to be conducted by the contractor before completing this report and Section VI of this report presents the specific analyses performed. In addition to comments on possible sensitivity analyses, public participants had specific suggestions on how to improve the presentation of the findings.

The rest of this report is divided into the following sections:

1. Section II presents a brief summary of the NWS analytical framework and the methodologies for calculating evaluation measures.

2. Section III discusses the purpose of evaluation measures, the process and criteria used to select evaluation measures, the evaluation measures used, and the methodologies used to execute evaluation measures.

3. Section IV discusses the purpose of strategies, the rationale for selecting actions, the methodologies for calculating the costs of actions, and the four NWS strategies.

4. Section V presents the findings of the evaluation of the four strategies.

5. Section VI presents the purpose of sensitivity analyses in the NWS analytical framework, the rationale behind each sensitivity analysis, and the findings from each analysis.

6. Section VII presents the conclusions from the evaluation of alternative strategies.

7. Appendix A contains the breakout of the maintenance dredging volumes used in Element L.

8. Appendix B contains the breakout of the other operations and maintenance expenses used in Element L.

9. Appendix C contains the evaluation of the environmental impacts of strategies.

10. Appendix D contains an explanation of the linehaul cost evaluation methodology used for analyzing channel deepening.

11. Appendix E contains a glossary of selected terms used in K2/L.

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
1	Upper Mississippi River	Minneapolis, MN to Mouth of Illinois River	1	Upper Mississippi
2	Lower Upper Mississippi River	Mouth of Illinois River to Mouth of Ohio River at Cairo, IL	2	Lower Mississippi River (Illinois River to Missouri River)
			3	Middle Mississippi River (Missouri River to Ohio River including Kaskaskia River)
3	Lower Mississippi River: Cairo to Baton Rouge	Mouth of Ohio River (Cairo, IL) to Baton Rouge, LA	4	Lower Middle Mississippi River (Ohio River to White River)
			5	Upper Lower Mississippi River (White River to Old River)
			6	Lower Mississippi River - Old River to Baton Rouge
4	Lower Mississippi River: Baton Rouge to Gulf	Baton Rouge, LA (including port) to Mouth of Passes and other channels and rivers	7	Mississippi River - Baton Rouge to New Orleans
			8	Mississippi River - New Orleans to Gulf
			25	Ouachita - Black and Red Rivers
			26	Old and Atchafalaya Rivers
			27	Baton Rouge to Morgan City, LA Bypass
5	Illinois Waterway	Chicago, IL (Guard Lock and T. J. O'Brien Lock) to Mouth of Illinois River	9	Illinois Waterway
6	Missouri River	Sioux City, IA to Mouth at Mississippi River	10	Missouri River

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
7	Ohio River	Head of navigation to Mouth	11	Upper Ohio River (Confluence of Monongahela and Allegheny at Pittsburgh, PA to Kanawha River)
			12	Middle Ohio River (Kanawha River to Kentucky River)
			13	Lower Ohio River - Three (Kentucky River to Green River)
			14	Lower Ohio River - Two (Green River to Tennessee River)
			15	Lower Ohio River - One (Tennessee River to Mouth)
			16	Monongahela River
			17	Allegheny River
			18	Kanawha River
			19	Kentucky River
			20	Green River and Barren River
			21	Cumberland River
8	Tennessee River	Head of navigation above Knoxville, TN to Mouth	22	Upper Tennessee River and Clinch River (Head of navigation to junction with Tennessee-Tombigbee Waterway)
			23	Lower Tennessee River (from junction with Tennessee-Tombigbee Waterway to Ohio River)
9	Arkansas River	Catoosa, OK (near Tulsa, OK)	24	Arkansas River (including Verdigris, White and Black Rivers)
10	Gulf Coast West	New Orleans to Brownsville, TX	28	GIWW West One (from New Orleans, LA to Calcasieu River)

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
10	Gulf Coast West	New Orleans to Brownsville, TX	29	GIWW West Two (Calcasieu River to Corpus Christi, TX)
			30	GIWW West Three (Corpus Christi to Brownsville)
			34	Houston Ship Channel
11	Gulf Coast East	New Orleans to Key West, FL	31	GIWW East One (New Orleans to Mobile Bay, including Mississippi River Gulf Outlet and Pearl River)
			32	GIWW East Two (Mobile Bay to St. Marks, FL)
			33	Florida Gulf Coast (St. Marks, FL to Key West, FL)
			38	Apalachicola, Chattahoochee, Flint Rivers
12	Mobile River and Tributaries	Head of navigation to Mouth	35	Black Warrior - Mobile Harbor (Black Warrior River - Head of Navigation to Mouth, Tombigbee River - Mouth of Black Warrior River to Confluence with Alabama River, Mobile River to Mobile Bay, Mobile Harbor)
			36	Alabama-Coosa Rivers
			37	Tennessee-Tombigbee Waterway
13	South Atlantic Coast	Key West, FL to North Carolina/ Virginia Border	39	Florida/Georgia Coast
			40	Carolinas Coast
14	Middle Atlantic Coast	North Carolina/Virgina Border to New York/Connecticut Border	41	Chesapeake and Delaware Bays
			42	New Jersey/New York Coasts

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
15	North Atlantic Coast	Hudson River from Waterford, NY to Mouth; New York/Connecticut Border to Canada Border	44	North Atlantic Coast
16	Great Lakes/St. Lawrence Seaway/New York State Waterways		43	New York State Waterways
			45	Lake Ontario and St. Lawrence Seaway
			46	Lake Erie
			47	Lake Huron
			48	Lake Michigan
			49	Lake Superior
17	Washington/Oregon Coast	Puget Sound to California-Oregon Border	50	Puget Sound
			53	Oregon/Washington Coast
18	Columbia-Snake Waterway/ Willamette River	Lewiston, ID to Mouth	51	Upper Columbia-Snake Waterway (Lewiston, ID to Bonneville Lock and Dam)
			52	Lower Columbia-Snake Waterway/ Williamette River (from Bonneville Lock to Mouth)
19	California Coast	California-Oregon Border to Mexico Border	54	Northern California (Oregon-California Border to San Francisco Bay)
			55	San Francisco Bay Area, Sacramento River, and San Joaquin River
			56	Central/South California (from San Francisco Bay to Mexico Border)

NWS REPORTING REGIONS AND ANALYSIS SEGMENTS

Region Number	Region Name	Description	Segment Number	Segment Name
20	Alaska		57	Southeast Alaska (panhandle)
			58	South Central Alaska Coast
			59	West and North Coasts of Alaska (including Aleutians)
21	Hawaii and Pacific Territories		60	Hawaii and Pacific Territories
22	Caribbean, including Puerto Rico and Virgin Islands		61	Caribbean, including Puerto Rico and Virgin Islands
			62	Rest of World (not included as part of a Reporting Region)

NWS REPORTING REGIONS AND ANALYSIS GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
I.	Farm Products			
		1	Corn	0103
		2	Wheat	0107
		3	Soybeans	0111
		4	Other Farm Products	0101, 0102, 0104, 0105, 0106, 0112, 0119, 0121, 0122, 0129, 0131, 0132, 0133, 0134, 0141, 0151, 0161, 0191
II.	Metallic Ores			
		5	Iron Ore and Concentrates	1011
		6	Other Ores (including Bauxite)	1021, 1051, 0161, 1091
III.	Coal			
		7	Coal and Lignite	1121
IV.	Crude Petrol			
		8	Crude Petroleum	1311

NWS REPORTING REGIONS AND ANALYSIS GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDW Code
V.	Nonmetallic Minerals			
		9	Sand, Gravel, and Crushed Rock	1442
		10	Limestone	1411
		11	Phosphate Rock and Other Fertilizers	1471, 1479
		12	Sulfur	1492, 1493
		13	Other Nonmetallic Minerals	1412, 1451, 1491, 1494, 1499
VI.	Food Kindred Products			
		14	Vegetable Oils	2091
		15	Grain Mill Products	2041, 2042, 2049
		16	Other Food Products	2011, 2012, 2014, 2015, 2021, 2022, 2031, 2034, 2039, 2061, 2062, 2081, 2092, 2094, 2095, 2099
VII.	Lumber and Wood Products			
		17	Logs (including Pulpwood)	2411, 2415
		18	Rafted Logs	2412
		19	Lumber and Plywood	2421, 2431
		20	Other Lumber and Wood Products	2491

NWS REPORTING REGIONS AND ANALYSIS GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
VIII.	Pulp, Paper and Allied Products			
		21	Pulp	2611
		22	Other Pulp and Paper Products	2621, 2631, 2691
IX.	Chemicals			
		23	Sodium Hydroxide	2810
		24	Crude Tar, Oil and Gas Products	2811
		25	Alcohols	2813
		26	Benzene and Toluene	2817
		27	Sulphuric Acid	2818
		28	Other Chemicals	2816, 2819, 2812, 2821, 2822 2823, 2831, 2841, 2851, 2861, 2876, 2891
		29	Nitrogenous Chemical Fertilizers	2871
		30	Potassic Chemical Fertilizers	2872
		31	Phosphatic Chemical Fertilizers	2873
		32	Other Fertilizer Products	2879, 2875
X.	Petroleum and Coal Products			
		33	Gasoline	2911
		34	Jet Fuel and Kerosene	2912, 2913

NWS REPORTING REGIONS AND ANALYSIS GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
X. (Cont'd)		35	Distillate	2914
		36	Residual	2915
		37	Other Petroleum and Coal Products, nec	2916, 2917, 2918, 2920 2921, 2951, 2991
XI.	Stone, Clay, Glass, and Concrete Products			
		38	Cement	3241
		39	Other Stone, Clay, Glass Products	3211, 3251, 3271, 3281, 3291
XII.	Primary Metals Products			
		40	Coke	3313
		41	Iron and Steel Primary Forms	3314
		42	Steel Mill Products (shapes, plates pipe and tube)	3315, 3316, 3317
		43	Primary Metals	3311, 3312, 3318, 3319, 3321, 3322, 3323, 3324
XIII.	Waste and Scrap			
		44	Metal Scrap	4011, 4012
		45	Other Scrap	4022, 4024, 4029

NWS REPORTING REGIONS AND ANALYSIS GROUPS

Reporting Number	Description	Analysis Number	Commodity	CCDWC Code
XIV.	Other Commodities			
		46	Marine Shells	0931
		47	Miscellaneous Forest Products	0841, 0861
			Fish	0911, 0912, 0913
			Ordnance	0911
			Tobacco	2111
			Textiles	2211, 2212, 2311
			Furniture	2511
			Printed Matter	2711
			Rubber Products	3011
			Leather	3111
			Fabricated Metal	3411
			Machinery	3511, 3611
			Transportation Equipment	3711, 3721, 3731, 3791
			Instruments, Optical Goods, etc.	3811
			Miscellaneous Manufacturers	3911
			Water	4111
			Commodity, nec	4112
			LCL Fre'ght	4113
			Department of Defense Cargo	9999
			Water Improvement Materials	4118

II - ANALYTICAL FRAMEWORK

This section presents a brief summary of the NWS analytical framework, the criteria for selection of the evaluation measures, and a discussion of the methodology for computing each of these measures. Evaluation measures assess the relative merits of strategies with regard to issues of national concern.

DESCRIPTION OF ANALYTICAL FRAMEWORK

The final integration framework is depicted in Figure II-A.[1] The five columns in the figure correspond to the four scenarios plus sensitivity analyses. The integration process is represented by the eight steps along the left side of the figure. Each of these steps is discussed briefly below.

Scenarios are alternative views of the future. They are collections of assumptions about related factors in the economy, society, or government that, taken together will affect the future use of the waterways for transportation.

The waterborne commodity flow projections are estimates of commodity flows that can be expected to move by water if there is adequate waterway capability to handle this traffic.[2]

---

[1]A detailed discussion of this analytical framework is presented in Section II of the Element K2 Report (Evaluation of the Present Navigation System).

[2]The detailed assumptions of each scenario and the waterborne commodity flow projections are presented in the Element K2 Report.

Figure II-A

National Waterways Study

Final Integration Framework

	Scenarios				
	Baseline	High Use	Low Use	Bad Energy	Sensitivity Analyses
	1	2	3	4	5
ASSUMPTIONS AND TECHNICAL ESTIMATES ABOUT UNCONTROLLABLE EVENTS					
WATERBORNE COMMODITY FLOW PROJECTIONS					
TRANSPORTATION CAPABILITY OF PRESENT WATERWAYS SYSTEM					
WATER TRANSPORTATION NEEDS					
APPLICATION OF STRATEGIES					
DESCRIPTION OF STRATEGY OUTCOMES					
EVALUATION OF STRATEGY EFFECTS					
SENSITIVITY ANALYSES					

Water transportation capability is the ability of the present waterways system to accommodate projected waterborne commodity flows safely and at a marine linehaul cost consistent with the historical cost relationship among transportation modes. Thus, water transportation capability involves estimating lock capacity; identifying major safety problem areas; and estimating the costs of marine linehaul operations.

Water transportation needs are the changes in the navigation system that would be required to handle current and projected waterborne commodity flows safely and at a marine linehaul cost consistent with the historical cost relationship among transportation modes.[3]

Having determined needs, it is possible to take actions according to alternative policy and top management directives. These alternative directives are strategies. The four NWS strategies include: continue present trends (Strategy I); refocus present resources (Strategy II); fully fund present system (Strategy III); and improve or expand waterways (Strategy IV).[4] The application of strategies is the process of determining what actions will be taken at what time and costs under different combinations of scenarios and strategies. The descriptions of strategy outcomes are the lists of actions taken to maintain and operate the present system; increase lock capacity; reduce safety hazards; enhance water transportation

---

[3]Transportation capability and water transportation needs are discussed in Sections IV and V of the Element K2 report (Evaluation of the Present Navigation System).

[4]Originally, it was envisioned that there would be six strategies. A strategy to reduce public support of the waterways (i.e., reduce aggregate public financing of the overall system) was determined to be inappropriate given the language of the congressional authorization. Another strategy to maximize utilization of existing public facilities was incorporated in part within Strategies I and II.

by enlarging port and channel dimensions; and reduce federal expenditures for waterways subject to an overall budget limit.

The evaluation of strategies is the assessment of the relative merits of strategies with regard to issues of national concern. Thirteen evaluation measures are computed at the national and/or regional levels for scenario-strategy combinations. In addition, the broad generic impacts of actions on the environment are discussed.

The final step of the integration framework is the sensitivity analysis. The purpose of these analyses is to determine the sensitivity of Element K2 and L findings to changes in key assumptions. Five sensitivity analyses were undertaken:

1. Evaluation of the present waterways system and selected strategies under a defense scenario.

2. Substitution of markedly higher coal exports in the high use scenario.

3. Development of new flows for sand and gravel on the Upper Columbia at Bonneville, "miscellaneous" cargo at the Inner Harbor Navigation Canal, and all commodities on the Arkansas, Monongahela, and Ohio Rivers.[5]

4. Evaluation of the effect of minor structural actions on lock capacity.

---

[5]Sensitivity analyses were originally envisioned for higher steam coal flows on the Kanawha River due to the establishment of a new terminal, and synfuel coal flows on the Monongahela and Upper Ohio due to a proposed plant; but these flows have already been incorporated in the four scenarios.

The results of these analyses are discussed in Section V of the K2 report (Evaluation of the Present Navigation System) as they affect the evaluation of the present system and Section VI of the L report (Evaluation of Alternative Future Strategies for Action) as they affect the evaluation of strategies.

III - EVALUATION MEASURES AND METHODOLOGY

PURPOSE OF SECTION

One of the most important activities in the NWS Integration process was the final selection of evaluation measures to be used in evaluating strategies. While this activity has no formal "slot" in the integration framework discussed in Section II, it in fact defined the form and content of the ultimate end products of the integration process. The purpose of this section is to document the process used to finally select the evaluation measures actually used, describe those evaluation measures, and describe the methodology used to execute the measures. The remainder of this section is organized into the following major topics:

1. Process for selection of evaluation measures.

2. Definition of evaluation measures.

3. Criteria for selection of evaluation measures.

4. Other considerations in selection of evaluation measures.

5. Evaluation measures actually used.

6. Methodologies for computing evaluation measures.

7. Evaluation measures and procedures considered and rejected.

8. Relationship of evaluation measures to strategies.

PROCESS FOR SELECTION OF EVALUATION MEASURES

The process of selecting evaluation measures began early in NWS and these early steps included a variety of media and are documented in different ways. The major steps in the process included:

1. A description of potential measures in the NWS workplan.

2. A presentation at the NWS Public Workshop in December of 1979.

3. Various meetings and briefings with Corps study staff during the first half of 1980.

4. The Final Integration Plan, submitted in draft form in May of 1980 and finalized in July of 1980.

5. The public briefing documents prepared in November of 1980.

This report represents the culmination of this process and provides the final definitive set of evaluation measures actually used. The measures presented here incorporate careful consideration of all the comments received from both public and Corps sources during this long process.

The process of finalizing the evaluation measures began in earnest in the Spring of 1980 with the preparation of early versions of the integration plan. During the preparation of this plan it became clear that a more formal structure for consideration of evaluation measures was required. A structure was developed and consisted of the following steps:

1. Definition of the evaluation measure concept.

2. Specification of criteria for selection of evaluation measures.

3. Review of prior project documentation to screen measures.

4. Development of a list of specific measures proposed for use.

This logical structure was followed in the development of the Integration Plan which was finalized in July of 1980. The measures specified in that plan have been used with some modification.

DEFINITION OF EVALUATION MEASURES

An NWS evaluation measure is defined as follows:

AN EVALUATION MEASURE IS AN INDEX OF RELATIVE "GOODNESS" OR "BADNESS" OF A STRATEGY FOR MANAGING THE WATERWAYS SYSTEM WITH RESPECT TO SOME IMPORTANT ISSUE OR CONCERN.

There are several key words in this definition which focus on the major attributes of an evaluation measure:

1. Index. A measure is an index similar to the way that a degree scale is an index of temperature.

2. Relative "goodness" or "badness". Measures are primarily intended to make comparisons.

3. Strategy. Measures are used to evaluate strategies, not the waterway system.

4. Important issue or concern. Measures are used to evaluate the effects of strategies on important issues as they relate to water transportation.

These definitional concepts were in turn applied in developing the criteria used for selection of evaluation measures.

CRITERIA FOR SELECTION OF EVALUATION MEASURES

Several criteria were developed for selecting evaluation measures and were documented in the Final Integration Plan in July of 1980. These criteria require evaluation measures to:

1. Address study objectives.

2. Address issues identified by the NWS Workplan and Element Studies.

3. Provide meaningful distinctions among outcomes.

4. Be limited to a reasonable number.

5. Avoid duplication.

6. Be objective.

7. Be verifiable.

8. Be distinguished from project level evaluation measures.

Each of these criteria is discussed under separate headings below.

(a) Measures Are Related to Study Objectives

The most important single criterion in selecting evaluation measures is that they provide a statement about the effectiveness of various strategies in meeting national water transportation needs. Any evaluation measure that does not serve this study objective and the issues surrounding it had no place in the integration process.[1]

[1]For example, many federal government policies and programs are oriented at either controlling or mitigating the bad effects of business cycles. While this is a major national issue it is different from long term transportation needs and no measure of the effect of waterways management strategies on business cycles has been included.

(b) The Relevant Issues Identified in the Workplan and Element Studies Are Addressed

Evaluation measures were selected to provide adequate coverage of the issues identified in the Workplan and element reports. The study was originally designed to ensure that the major issues affected by strategies for meeting water transportation needs would in fact be addressed. Thus, the prior element work played a key role in determining what evaluation measures were appropriate for inclusion.

(c) Measures Provide Meaningful Distinctions Among Outcomes

Evaluation measures must be able to make distinctions among outcomes. Although it was important not to prejudge the effectiveness of any particular measure, some of the prior technical work suggested that certain measures outlined in the Study Workplan were not likely to show any significant variation across strategies. This was particularly true of concerns studied in Element G (Analysis of Navigation Relationships to Other Water Uses).

(d) The Number of Measures Are Limited

The number of evaluation measures is restricted to a reasonable number. There are several reasons for this. Most importantly, the study results must be clear, useful, and understandable. The study results will be presented to multiple audiences. These audiences include the Congress, the Corps, other government agencies, carriers, shippers, port authorities, and the general public. Some of these audiences will be familiar with water transportation issues and others will not be. Clearly, a large number of evaluation measues makes the analysis more difficult and, to the extent that some of these measures are of a local or regional nature, attention will be directed away from national issues.

(e) Evaluation Measures Are Not Duplicative

The evaluation measures included in this integration process have been selected so as to avoid excessive duplication and over-lapping in the coverage of a single major issue. Evaluation measures that address an issue in a less thorough or a more indirect manner than other measures were minimized. Thus, it was necessary to examine which of several related measures does a better job of addressing an issue directly. A simple statement that a candidate measure is "another way of looking at the same problem" was not a sufficient condition for its inclusion.

(f) Evaluation Measures Are Objective

Evaluation measures should be objective where possible. Minimum reliance on subjective judgments is desirable.

(g) Evaluation Measures Are Verifiable

All evaluation measures should be verifiable by third parties. An "audit trail" of assumptions, data, analysis, and conclusions is presented so as to allow others to place confidence in the study. This does not mean that literally every calculation is displayed. Evaluation measures which are not linked to the basic research of the study have been avoided.

(h) NWS Evaluation Measures Are Not Project Evaluation Measures

The entire NWS effort has been structured to avoid passing judgment on specific projects. NWS is not a global "feasibility study" which attempts to justify a particular set of possible investments or improvements.

The overall study objective is the assessment of the capabilities of the nation's waterway system to meet needs, not net benefit maximization or any other optimization concept. Accordingly, no measure of "economic benefits" per se has been included.

OTHER CONSIDERATIONS IN SELECTION OF EVALUATION MEASURES

In addition to the formal criteria spelled out above, several other issues regarding the selection of evaluation measures and procedures were also identified. Some of these issues were identified during the course of reviewing the prior NWS work and some were the result of analyses articulated during the preparation of the Final Integration Plan. All helped shape the final list of measures and are discussed below:

(a) Incorporation of Prior Work

Based on the premise that prior work in the NWS elements had identified the major concerns and developed ample lists of potential evaluation measures, it was decided to limit the scope of the evaluation process to the measures and procedures suggested in those studies unless a clear reason for innovation presented itself. This work had already received at least some review and it was reasonable to conclude the major concerns and potential measures had already been well identified. This facilitated the focusing of the final selection process.

(b) Means vs. Ends

A certain amount of confusion was found in some of the previously proposed evaluation measures between the objective of the waterway system (meeting water transportation needs) and the means of achieving the objective (providing additional lock capacity, etc.). The conclusion was reached that the configuration of the waterway system and the actions taken to meet needs, while of interest, were not themselves valid evaluation measures. The number and types of actions taken in a strategy were redefined as "strategy outcomes" and a separate niche in the final

integration framework was established for them. Thus a whole category of potential evaluation measures suggested by Element K1 relating to actions and physical performance were eliminated from further consideration as evaluation measures.

(c) National vs. Regional Treatment

Since NWS is a national study, the main emphasis was to select measures which permit the evaluation of strategies on a national basis. Most of the measures actually used are built up from analytical segment level detail and consequently it is possible to provide similar, or the same, measures at the regional level. However, some measures cannot be computed at less than the national level.

EVALUATION MEASURES ACTUALLY USED

The following thirteen evaluation measures were used to assess each strategy:

1. Traffic accommodated (in tons) as a percentage of projected usage (in tons).

2. Traffic (in tons) not accommodated.

3. Traffic accommodated (in tons) as a percentage of production plus imports of key waterborne industries.

4. Private marine linehaul costs.

5. Annual savings in linehaul costs for domestic traffic.

6. Public expenditures for the operations, maintenance, rehabilitation, and improvement of the present waterways system (displayed as a single cumulative total in this report).

7. Fuel tax revenues collected under Public Law 95-502. (This fuel tax was explicitly incorporated into the basic assumptions of the NWS Workplan.)

8. Average lock utilization.

9. Increase in projected usage from 1977 to 2003.

10. Share of hazardous commodities as a percentage of projected use.

11. Average tow size as a percentage of maximum accommodated tow size.

12. Average lock delay.

13. A qualitative assessment of environmental impacts of strategies.

METHODOLOGIES FOR COMPUTING EVALUATION MEASURES

Criteria similar to those used for selecting evaluation measures were used to develop and select methodologies for the NWS integration process. The methodologies used are described briefly below.

(a) Traffic Accommodated Versus Projected Usage

The projections of waterborne commodity flows are based upon a number of macroeconomic and industry assumptions, but are not influenced by any single constraining lock or set of constraining locks. Waterway traffic, as defined by NWS, refers to that proportion of projected use that can actually be accommodated after taking into account shortfalls in lock capacity using a consistent methodology for all locks.

In order to estimate traffic accommodated, it was necessary to forecast the expected usage and capacity of every commercially important lock within the system. Estimates of projected usage and capacity were made for 177 locks (the number of individual chambers included is much larger) for seven different time periods (1977-2003). Although the number of locks analyzed was large, the methodology was simple and was not designed to replicate

project level analysis, either in the traffic forecasts or in the capacity calculations.

Projected usage at locks was estimated from the forecasts of waterborne commodity flows developed in Appendix A to the Element K2 Report (Evaluation of the Present Navigation System) and the historical relationship of traffic at an individual lock within a particular segment as indicated by an analysis of the detailed port-equivalent movements of waterborne commodities for 1969 to 1977.[2]

Capacity at locks was estimated from detailed historical data collected at each lock. These data included, but were not limited to:

1. Average tow size.
2. Average barge lading.
3. Percent of time that barges/vessels were empty.
4. Components of lockage times.
5. Downtime.

These historical data had to be adjusted to take into account changes in the mix of traffic transiting a lock

---

[2]Port-equivalents represent a further disaggregation of the present system into over 200 components. Generally, the boundaries of port-equivalents coincide with locks and dams. Thus, it is possible to estimate the actual waterborne traffic transiting a lock using the seven categories of historical traffic available at the port-equivalent level. These include through, inbound, and outbound traffic moving upbound and downbound as well as traffic moving within a port-equivalent.

over the forecast period. A complete explanation of the data and methodology used are in Appendix C of the K2 Report (Evaluation of the Present Navigation System).

Where lock capacity was not adequate to accommodate all of this usage, an estimate of the amount of traffic in tons not accommodated at a specific lock could be made. In order to determine the number of tons not handled due to lock constraints throughout the system, it was necessary to identify the principal shortfalls in lock capacity first and then adjust traffic everywhere else to reflect these shortfalls.

For example, shortfalls in lock capacity occurred at Locks and Dam 26 as well as several Illinois Waterway locks under all four scenarios by the year 2003 or earlier. However, the shortfall in Locks and Dam 26 occurred earlier, was so much larger, and the percentage of traffic transiting both Locks and Dam 26 and the Illinois Waterway locks was so high (50 percent of the traffic passing Locks and Dam 26 also passed the Illinois Waterway locks) that it was necessary to reduce the Illinois Waterway traffic by taking into account the loss in traffic caused by Locks and Dam 26 first, before estimating the loss in traffic caused by shortfalls at individual Illinois Waterway locks.

Having completed this process for each lock in the system for each of seven different time periods, it was possible to calculate the percentage of projected usage actually accommodated by a strategy at the national and regional levels for 1977-2003.

(b) Traffic in Tons Not Accommodated

This measure is the amount of projected usage in tons that could not be accommodated by a strategy due to shortfalls in lock capacity. This measure was calculated in the same manner as the previous measure.

(c) Traffic Accommodated Versus Production Plus Imports of Key Waterborne Industries

This measure is the amount of waterborne traffic for each of four key industries divided by the total commodity supply (production plus imports) of each of these industries. These four industries include the agriculture, steel, coal, and petroleum industries.

The commodities within the agriculture industry include corn, soybeans, wheat, vegetable oils, grain products, and other farm and food products. The steel industry includes iron ore, other ores, coke, iron and steel primary forms, steel mill products, and primary metals. The coal industry is self-explanatory, while the petroleum industry includes crude petroleum, gasoline, jet fuel and kerosene, distillate, residual, and other petroleum and coal products.

These measures are calculated at the national level and reflect the industry impacts of lock capacity shortfalls on the four major waterborne industries. The objective is to evaluate the effects of possible "disruptions" of the logistic systems of key industries.

(d) Private Marine Linehaul Costs

This measure is the private operating costs (in cents per ton-mile) of the linehaul operations of tows on the inland segments and vessels on the Great Lakes. The public costs of waterway operations, maintenance and improvement are excluded. Furthermore, the costs of the linehaul operations of foreign trade shipments are not estimated. The measure of private marine linehaul costs are displayed at the regional, industry, and national levels for each of the seven time periods.

In order to estimate these linehaul costs, it was necessary to obtain commodity and segment-specific data for:

1. Average barge/vessel lading.

2. Average tow size.

3. Average speed.

4. Lock delays.

5. Percent of time that barges/vessels were empty.

6. Average horsepower of towboat/vessel.

7. Average fuel consumption.

8. Improvement in the efficiency of fuel use over the forecast period.

9. Fuel price including current waterway user-charges as mandated by Public Law 95-502.

10. Non-fuel operating costs.

Variables such as average lading, tow size, and percent empty that can be expected to change with changes in the mix of traffic passing through a segment were adjusted for each time period after 1977. All costs were estimated in constant 1977 dollars, but fuel prices reflect real increases over time due to domestic decontrol, higher foreign crude oil prices, and waterway user taxes. A detailed explanation of the data and methodology used are provided in Appendix D of the Element K2 Report (Evaluation of the Present Navigation System).

(e) Annual Savings in Linehaul Costs for Domestic Traffic

This measure was computed to provide an alternative view of the impacts of actions taken under the various strategies. It was computed as the product of the difference in regional average linehaul costs for all commodities multiplied by the projected use in ton-miles. This

measure was computed only for those regions where ton-miles had been projected, namely the Great Lakes, the Mississippi River and tributaries, and the Gulf Coast shallow draft waterways. These are also the regions where the major changes in domestic linehaul cost occur. Only the effect of alleviating congestion at Bonneville Lock in the Columbia/Snake Region is not captured.

(f) Public Expenditures

The public costs of maintaining, operating, rehabilitating and improving the waterways were tabulated in 1977 dollars for 1977 to 2003.

Maintenance includes expenditures for dredging and dredge disposal. The real cost increases that can be expected to be incurred as a result of higher fuel prices (approximately 20% of current dredging expenditures are for fuel) and compliance with existing environmental regulations were estimated for each of the 61 analytical segments. Compliance with environmental regulations can be expected to add considerable costs to dredging as existing, environmentally acceptable disposal sites are filled.

Expenditures for other operations and maintenance were also estimated. These are primarily for locks.

Rehabilitation costs were estimated for locks based on the functional relationship between such historical costs, on the one hand, and the age, size, and lift of each lock in the system, on the other hand. The rehabilitation costs of other waterway structures in segments without locks were estimated as an annual percentage of the historical first costs of these structures. A real rate of cost increase (namely 1.25 percent per year) for rehabilitating all waterway structures was also applied.

Construction costs for actions to increase lock capacity, improve safety, and enhance water transportation by deepening or widening channel and port dimensions were also estimated. Construction costs for these actions were estimated from prior Corps studies and/or engineering

analyses of specific sites. As in the case of rehabilitation, an annual rate of increase has been applied to these costs to reflect real cost increases over time. A detailed discussion of these costs and how they were treated can be found in Section IV of this report.

To simplify the presentation in this report, a single number for the cumulative total cost is displayed in Section V.

(g) <u>Fuel Tax Revenues</u>

Fuel tax revenues as collected by Public Law 95-502 were also estimated. These ta‸ s apply on the sale of marine fuel for inland navigation on specified rivers and channels only. These revenues were estimated by calculating the number of gallons of fuel consumed by towboats while in route or waiting in line to pass through locks.

(h) <u>Average Lock Utilization</u>

Lock utilization is lock traffic, adjusted for tons not handled, divided by lock capacity. It was calculated at the lock, segment, and finally regional levels for the seven time periods based on the results for all the locks included in Appendix C of the Element K2 report (<u>Evaluation of the Present Navigation System</u>).

(i) <u>Increase in Projected Use</u>

This is one of four evaluation measures used to highlight those segments that can be expected to have additional safety problems in the future. Specific sites historically posing safety problems were identified in Section IV of the K2 report (Evaluation of the Present Navigation System). By way of contrast, these measures are designed to highlight areas where safety problems might develop in the future. This measure is simply the increase in projected use (in tons) from 1977 to 2003.

(j) Share of Hazardous Commodities Versus Total Use

This measure is the percentage of total waterborne commodity flows represented by hazardous commodities (crude petroluem, petroleum products, and chemicals). This is another measure to highlight segments with potential safety problems in the future. Although hazardous cargoes do not necessarily increase the frequency of accidents, they can increase the severity of accidents.

(k) Average Tow Size Versus Maximum Accommodated Tow Size

This measure estimates how closely average tow sizes approach the maximum tow sizes that can safely be accommodated on the waterways. This measure is a proxy for the safety hazards posed as a growing proportion of tows on a segment operate at or near the maximum safe size. Average tow sizes were calculated for each segment and time period after taking into account the mix of commodity traffic. Maximum accommodated tow sizes reflect actual channel conditions and were obtained primarily from Element K1 (Engineering Analysis of Waterways Systems). A sharp increase in this ratio might indicate that the frequency of accidents could be expected to increase.

(l) Average Lock Delay

This measure is the number of hours that each towboat or vessel is delayed at a lock and is used as a proxy for increased safety problems arising from congestion. The measure was calculated at the lock level and aggregated to the segment and regional levels. Long delays at locks

indicate that the increased congestion may well lead to a higher rate of accidents.[3]

EVALUATION MEASURES AND PROCEDURES CONSIDERED AND REJECTED

The purpose of this discussion is to describe briefly two of the more significant decisions regarding the evaluation process not documented fully elsewhere. It is not desirable or necessary to review the application of the selection process to all the potential measures considered in this integration activity. Rather this discussion is provided to illustrate the application of the process in two important areas and report the results of the process for those two areas.

(a) Evaluation of Other Water Uses

When the NWS workplan was prepared it was based on the premise that other water uses had high levels of interaction with navigation. A large amount of study resources was devoted to this subject area (Element G -- Analysis of Navigation Relationships to Other Water Uses). During the course of this work a large list of potential measures was developed for possible use in integration. The eventual conclusion of Element G was that interaction was minimal and significant only in a few regions (e.g., the Missouri River) which are minor components of the navigation system. Thus no evaluation measures for other water uses were included in the final integration plan and none are presented in this report because the issue failed the test of national significance.

---

[3]Average lock delay is estimated using the equation described in the Element K1 Report (Engineering Analysis of Waterways Systems). The equation was modified when more than one chamber was present at a site by adding the estimated capacities of the individual chambers and by adding the values of the delay parameters for the individual chambers after weighting them by their capacities.

(b) Evaluation of Environmental Impacts of Strategies

Another issue of major concern throughout NWS was the treatment of environmental concerns. While there is room for disagreement about the nature and direction of environmental impacts associated with the present waterways system and possible strategies for managing them, the environment remains a priority concern with many private citizens and groups and public agencies, including the Corps of Engineers.

The conclusions of the environmental analysis (Element M -- Analysis of Environmental Aspects of Waterways Navigation) were carefully reviewed and several alternative approaches to the environmental evaluation were considered in light of these conclusions. Eventually the construction of numerical indices for four categories of impacts (terrestrial habitat, aquatic habitat, water quality, and wetlands) was attempted. This approach was described in the public briefing document mailed out prior to the November 1980 public meetings. However, the results of the analysis were never reported because the procedure used did not provide meaningful results at the level of aggregation attempted. Therefore, it was decided to fall back on a qualitative verbal analysis and this is included in this report. In this case the numerical approach attempted failed the criteria of verifiability and objectivity.

RELATIONSHIP OF EVALUATION MEASURES TO STRATEGIES

While the present waterways system was evaluated only on the basis of water transportation needs (lock capacity, linehaul cost, and safety), strategies are evaluated not only on how well they meet water transportation needs, but they are also evaluated for their performance across a variety of national issues. However, strategies are not formulated with regard to all these other issues. Rather they are formulated to meet water transportation needs. The four NWS strategies are described in detail in the next section of this report.

IV - STRATEGIES FOR ACTION

INTRODUCTION

This section presents the four strategies developed and analyzed during this phase of the integration process. The concept of a "strategy" is defined and discussed. The rationale or philosophy underlying each strategy is described and the decision rules specified. Actions are formulated for each strategy and the selection of individual actions is documented. The cost components of strategies are also discussed and the methodology for cost escalation discussed.

PURPOSE OF STRATEGIES

(a) Objectives of Strategic Analysis

The objectives of strategic analysis as executed in the integration phase of NWS were not to develop a single "recommended plan" or to conduct project level analysis. Rather, the primary objective as described in the NWS workplan was to apply and evaluate logical consistent strategies in an even handed manner to the entire navigation system from a national perspective. The intent of the analysis was to capture a reasonable range of distinctive approaches to managing the controllable human activities affecting the national navigation system.

(b) Definition of a Strategy

Strategies are defined simply as alternative sets of top management policies and directives to federal agencies for taking actions to meet water transportation needs. Private and nonfederal agencies are excluded from NWS strategies and the focus is on activities of traditional federal water resource agencies as they relate to commercial navigation. Congressional actions are incorporated into this concept.

(c) Policy and Top Management Directives

Strategies are meant to represent distinct conceptual approaches to meeting water transportation needs. As a consequence, it is appropriate to think of strategies in terms of alternative top management directives rather than sets of detailed programs or plans for action based on project level analysis.

For example, Congress, the Corps of Engineers and other government agencies have a broad range of options available in addressing such water transportation problems as:

- Shortfalls in lock capacity.
- Channel maintenance.
- Old, unreliable waterway structures.
- Restrictive bridges.
- Narrow, hazardous channels.
- Congested ports.

For each of these problems, the federal government has some distinct policy options. The federal government, for example, can take major structural actions to add capacity at potentially constraining locks in advance of the build-up of long delays and to reduce remaining hazards to navigation in a timely manner. On the other hand, the federal government can choose to squeeze more performance out of the existing system and take major structural actions to add capacity or improve safety only when numerous minor or non-structural actions have been implemented. The NWS strategies and their evaluation are meant to illustrate some of these broad options available to the Congress, Corps of Engineers, and other government agencies in meeting the real needs of commercial water transportation users.

Strategies have, thus, been formulated not as detailed plans nor programs and no attempt has been made to duplicate the extensive planning process that the Corps undertakes when reviewing the relative merits of specific waterway projects. For example, at some locks, a series of minor and nonstructural actions are appropriate and these might include constructing mooring cells, extending guidewalls, installing winches, processing tows in sequence of four up and four down, and providing helper boats. At any given lock in the system, one or more of these actions may be inappropriate. While our assessment of lock capacity has attempted to incorporate the effects of a few widely applicable actions (namely the elimination of the extra chambering time lost for the making and breaking of tows, elimination of time lost for processing recreation traffic, and implementation of a four-up/four-down lock operating policy), it has not attempted to replicate the kind of detailed lock analysis that the Corps routinely undertakes before actually implementing minor and nonstructural actions.

Just as in the case of actions to increase lock capacity, there are numerous site-specific actions appropriate for improving safety. Some of these actions for dealing with conflicts posed only by bridges might include training of vessel and bridge personnel; building or improving fenders and pilings; avoiding bridge locations near bends; removing low-use, obstructive bridges; widening, straightening, or deepening approach channels; reducing cross currents; providing range markers and lights near bridges; locating sector lights; installing bridge pier radar reflectors; improving vessel steering; using bow thrusters; limiting hazardous or polluting cargo movements under poor navigation conditions; and so on. At any one bridge, a few selected actions might be appropriate and detailed project studies would make such recommendations based on an assessment of the relative benefits and costs. For purposes of the NWS, it is adequate to indicate where one or more of a basket of safety actions might be appropriate and to provide a generalized cost estimate for taking one or more possible actions at each site.

(d) Water Transportation Needs

Another key term defining strategies is water transportation needs. As noted at various public briefings and again in the introduction to this document, water transportation needs have been defined for NWS as the changes in the navigation system which would be required to handle current and projected waterborne commodity flows safely and at a linehaul cost that is consistent with the historical cost relationships among transportation modes. The term "needs" is not intended to suggest changes in the navigation system which must be undertaken at any cost. Water transportation needs are identified by assessing the present waterway system's ability to handle present and projected waterborne commodity flows. It should be emphasized that these projections assume that no major channel deepening or widening actions that would change the historical cost relationship between water and other modes of transportation will take place.

Prior technical research conducted for the NWS concluded that at least three separate analyses of the present system's capability to handle traffic are appropriate. These analyses are:

1. Lock capacity.

2. Private costs of the linehaul portion of waterborne shipments.

3. Water transportation safety.

Prior technical research found that locks are the principal constraints to present and projected waterborne commodity flows; that shifts from marine to competing modes of transportation rarely take place without major shifts in relative modal costs; and that the potential for vessel control accidents (collisions, groundings, and rammings) are often increased if there are unusual situational factors (bends, bridges, locks, and so on) and/or heavy traffic.

It should be noted that inadequate terminal capacity at ports can also cause delays or pose safety problems.

But, terminals have traditionally been financed by private interests and/or state and local governments. The NWS is concerned primarily with those actions that have traditionally been taken by federal government agencies acting at the behest of Congress. Thus, actions taken at ports for the NWS will include safety actions (establishment of enhanced vessel traffic services, for example) and channel-deepening actions, but not actions to increase terminal capacity.

CRITERIA FOR DESIGN AND SELECTION OF STRATEGIES

Several criteria were applied in the development of NWS strategies. These are discussed in turn.

(a) Orientation to Water Transportation Needs

The most important concept in defining and selecting strategies is the requirement that strategies address water transportation needs. Needs arise when lock capacities of the present system are unable to handle water transportation projected use. Needs may also rise from an analysis of safety problems or changes in the historical cost competitiveness of water transportation with respect to other modes. Actions are taken to remove constraints on system capabilities or address safety problems. Strategies are focused on selecting and applying actions to needs. Other considerations such as environmental impacts are issues, but they are not water transportation needs.

Two strategies in particular were articulated in the planning phase of the integration task which were dropped from further consideration because they were not considered to be oriented at meeting commercial water transportation needs. These strategies included concepts of demand management and reduced public support.

(b) Orientation to Service Levels

Service levels are defined as those waterway features or characteristics which influence private user costs without necessarily restricting capacities. For example, delays at hazardous locations may increase linehaul cost, while all tonnage can be passed. All strategies had to incorporate an attitude towards service levels as a strategic objective. One of the four NWS strategies (Strategy IV) is defined in terms of a service level orientation.

(c) Coverage

The strategies selected were defined to provide adequate coverage of the range of emphasis on different types of actions, constraints, and logical strategic goals. For example, some strategies incorporate budget constraints and others do not.

(d) Differentiation

Where one strategic concept was dominated by another, the dominant strategy was selected. This was done to avoid duplication and inclusion of strategies that were only marginally different. The overall objective was to design and select strategies that were different enough to hold strong promise of yielding different results.

(e) Mismanagement

An additional criterion that evolved as strategies were finalized was the avoidance of mismanagement. Each strategy had to be logically consistent. Decision rules and actions would not be included that resulted in absurd outcomes that did not meet strategic goals.

(f) Use of Prior Work

One limitation imposed on strategies, and the entire integration process, was to restrict the amount of original analytical work as much as possible. The intent was to

build on prior work, including various Corps studies, rather than to "reinvent wheels" with limited resources and time.

(g) Limitations Imposed by Data

A final criterion applied to strategies was to limit strategies to actions and decision rules that could be supported by the data bases available. Where data bases were insufficient to support a higher level of detail in analysis, strategies were limited accordingly in their scope so as to be consistent with available data.

DESCRIPTION OF STRATEGIES

(a) Range of Actions

Since strategies are sets of rules for taking discrete actions, a range or set of permissible actions consistent with the scope of the strategies had to be defined. As a result of the review of previous NWS work, and a process of ongoing review with the Corps of Engineers, actions consistent with specific strategic objectives were identified. These actions were identified based on the following set of decisions about the nature of the strategic analysis to be conducted:

1. On the basis of prior NWS work, "capability" was defined as encompassing capacity, safety, and linehaul cost.

2. Actions were to be restricted to those assigned by Congress to the traditional federal water resources agencies.

3. The basic conclusions of the prior NWS work were accepted and would be utilized in the formulation of strategies.

4. Strategies would be designed to meet needs. Conversely, strategies would not shape needs to fit estimated capabilities. The only exception to this rule was that withdrawal of federal financial support for customary public actions would be allowed if an overall budget limit for commercial navigation was included in a strategy.

Further, the conclusions of prior work clearly indicated that specific actions would be required to modify capabilities to meet needs as follows:

1. Since locks are the only constraints to capacity identified within the time horizon and scope of the study, all actions concerned with capacity would deal with locks.

2. Since channel dimensions are the primary physical determinants of linehaul cost, strategies concerned with changing linehaul cost would deal with channel dimensions.

3. Since the factors affecting safety that fall within the scope of strategies are mostly obstructions to navigation, all strategies would have to address the identified problem areas.

4. Since most actions consume resources, public costs would have to be estimated, and a mechanism for allocating funds would have to be specifically addressed in each strategy.

These limitations on strategies and major conclusions in turn strongly shaped the final formulation of four distinct strategies.

(b) Four NWS Strategies

The titles of the four strategies are:

- I - Continue present trends with fixed real budget
- II - Refocus present resources on present system
- III - Refocus expanded resources on present system
- IV - Improve waterways system

Strategies I and II are essentially alternative means of meeting water transportation needs subject to annual

budget limits on public waterway transportation expenditures. Under both strategies, the annual budget limit is equivalent in constant dollars to the Corps' average annual navigation budget during the mid-1970s of approximately $585 million in 1977 dollars. This budget represented approximately $180 million for channel maintenance, $125 million for operation of waterway facilities, and $280 million for construction. There were no expenditures for rehabilitation of navigation structures which could be separately identified from construction and operations and maintenance.

However, the similarity between Strategies I and II stops here. On the one hand, Strategy I gives top priority to funding the operations, maintenance, and rehabilitation of the present waterway system. Spending for channel maintenance increases in accordance with the cost increases that can be expected to be incurred by the Corps due to higher energy prices and compliance with existing environmental regulations, subject to the overall budget limit. Over time, of course, this priority implies that less resources will be available for construction of additional lock capacity and safety actions.

On the other hand, Strategy II deals with the problem of a constant dollar budget by allocating available resources to the operations, maintenance, rehabilitation, <u>and</u> construction of additional lock capacity for those waterways with relatively low ratios of operations and maintenance expenditures per ton-mile of traffic handled. This reallocation of resources to more cost-effective waterways is at the expense of the operations, maintenance, and rehabilitation of less cost-effective waterways.

In order to deal with the problem of a fixed budget under Strategy II it was necessary to develop some means of classifying waterways and ports. As will be discussed, the inland water segments are classified into three categories (Class "A", "B", and "C") based on the public costs of operating and maintaining these segments per ton-mile of projected use. It was also necessary to distinguish between secondary and primary ports in order to make sure that the needs of the primary ports were met.

It should be emphasized that the classification of inland segments into three categories of cost-effectiveness and the classification of ports into major and secondary ports are somewhat arbitrary and they are not proposed as schemes for adoption. However, Congress, the Corps of Engineers, and other government agencies may be unwilling to meet all the water transportation needs of commercial users through the year 2003 and, as a result, they may have to consider some means of assigning different priorities to meeting all these needs.

In sharp contrast to Strategies I and II, Strategy III assumes that there are adequate funds to meet water transportation needs. All requirements for operations, maintenance and rehabilitation are met as well as requirements for providing adequate lock capacity and safety. However, no actions are taken for the express purpose of improving linehaul cost.

Strategy IV is also a contrast to the other three strategies. In addition to meeting water transportation needs for additional lock capacity and safety and to improve linehaul cost this strategy assumes that actions are taken to deepen existing channels, such as the Mississippi, Illinois, and Ohio Rivers as well as five deep-draft ports. These actions are taken as part of a deliberate policy to reduce the private costs of using marine transportation and to improve the level of service to water transportation users. No budget limit is imposed in Strategy IV.

Table IV-1 summarizes the important differences in priorities among the four strategies for action.

DESCRIPTION AND SELECTION OF ACTIONS

The discussion that follows presents the detailed rationale supporting the selection of actions for NWS strategies. First, actions for NWS strategies are defined.

Table IV-1

Strategy Decision Priorities[1/]

Decision Rules	Strategy I	Strategy II	Strategy III	Strategy IV
1. Operation, Maintenance and Rehabilitation	Meet all O&M needs for Class "A" segments and major ports.[2/] If funds available, meet O&M needs for Class "B" segments. If funds available, meet O&M needs for Class "C" segments, secondary ports, and side channels.	Same as I, except actions for adding lock capacity in Class "A" segments have priority over the needs for operations and maintenance of Class "B" and "C" segments as well as secondary ports.	Funding of channel maintenance needs to maintain 1975-1977 reliability and complete funding of operations and rehabilitation needs.	Same as III, but fund annual deferred maintenance dredging as well.
2. Lock Construction	Add lock capacity at 95% utilization of practical capacity -- if adequate funds are available.	Same as I, but lock capacity actions for Class "A" segments are made before meeting the operation and maintenance needs of Class "B" and "C" segments.	Add lock capacity at 95% utilization wherever it occurs.	Add lock capacity at 85% utilization wherever it occurs. Replace selected obsolete locks.
3. Safety	Take minor and non-structural actions in regions with traffic growth of no less than 10,000,000 tons by year 2003, if funds are available.	Same as I, but safety actions for regions with traffic growth of no less than 10,000,000 tons are given priority over the need for operation and maintenance of Class "C" segments.	Take minor and non-structural actions in regions with traffic growth of no less than 10,000,000 tons by the year 2003.	Similar to III, but take some major structural actions to alter or replace bridges and widen reaches.
4. Channel and Port Deepening	No actions	No actions.	No actions.	Deepen Mississippi, Illinois, and Ohio Rivers. Deepen Galveston, New Orleans, Mobile, Norfolk, and Baltimore to 50' or more. Widen the Tombigee River south of Demopolis.

NOTES: 1/ It is assumed that the Red River and Tennessee-Tombigbee projects and the single 1,200' lock replacement project at L&D 26, the 12' channel from Baton Rouge to Cairo, the additional lock at Pickwick Lock and Dam, Vermilion Lock on the Gulf Intracoastal Waterway, and replacement of Locks 6 and 8 on the Ouachita, are completed as part of the "present system". These projects will prevent any new major actions for lock construction and safety from being taken under Strategies I and II until after 1990 due to assumed funding limits.

2/ Class A, B, and C segments and major and secondary ports are defined on pages IV-24 and IV-22, respectively.

AN ACTION IS A DISCRETE CONSTRUCTION ACTIVITY: CHANGE IN LEVEL OF OPERATIONS, MAINTENANCE, AND REHABILITATION ACTIVITY: CHANGE IN LOCK OPERATING POLICY: OR CHANGE IN LEVEL OF TRAFFIC MANAGEMENT (VTS).

Thus actions are identified with a specific location and time of occurrence as distinct from strategies which are applied over time across the entire system. The discussion that follows is organized into various types or classes of actions formulated for the different strategies.

(a) Actions at Locks to Increase Capacity

As discussed in Section IV of the K2 Report (Evaluation of the Present Navigation System), actions at locks fall into three categories; nonstructural actions, minor structural actions, and major structural actions. As was also discussed in the K2 Report, the capacity of locks in the present system was calculated assuming that of a mix of nonstructural actions would be implemented. In many cases, similar results could be achieved by a mix of minor structural actions working with, or separate from, nonstructural actions. In a few cases of unusual lock configurations, coupled with reasonable data, analysis suggests that large increases in lock capacity could be achieved by minor structural actions. These were documented in the sensitivity analysis of lock capacity in Appendix E of the K2 Report.

Major structural actions are of two basic types. Either a new chamber is added at a site and existing chambers continue to be used, or new chambers are added and existing chambers are either taken out of service or physically replaced. A major consideration in selecting a major structural action was the size of the new chamber in relation to traffic characteristics. In general, 1,200' x 110' chambers were selected to eliminate double lockages where these occurred. Smaller chambers (110' x 600') were used where double lockages either did not occur or were not expected to occur. Other chamber sizes were also specified where appropriate.

Another consideration influencing the size of the chamber to be built was the age of the existing chamber. In those cases where adding either a 600' or 1,200' chamber would fulfill projected capacity shortfalls, the merits of adding a single larger chamber combined with taking the existing chamber out of service were weighed against simply adding a second chamber of the same (smaller) size as the existing chamber combined with keeping the existing chamber in service. This choice was available only at sites where double lockages occurred or were expected to occur. The choice was between greater first cost for a larger chamber versus the projected stream of rehabilitation costs (an increasing function of age) for the existing chamber. An examination of the generalized cost estimates indicated that construction of a single larger chamber combined with removing the existing chamber (or chambers) from service would probably yield a higher return in most cases. Individual locks were not analyzed on a case-by-case basis to select an economic optimum.

The result of this analysis was an array of major structural actions at sites with relatively high utilization. This array was then used to describe major actions selected under the decision rules for each strategy to meet lock capacity shortfalls. This array of major structural actions to increase lock capacity is shown in Exhibit IV-1.

(b) Safety Actions

Actions to improve safety also include a range of nonstructural, minor structural, and major structural actions. Nonstructural actions are limited to new or enhanced Vessel Traffic Service Centers established and operated by the Coast Guard. The purpose of such actions is to reduce the likelihood of collisions between vessels and/or tows in heavy traffic areas.

Minor structural actions include actions at bridges, locks, and at unfavorable channel reaches. These actions include actions to reduce the likelihood of accidents such as radar reflectors, radar transponders, improved and increased aids to navigation (channel markings), mooring cells, and guidewalls. Also included are actions to minimize or reduce damage in the event of an accident such as fenders at bridges.

Major structural actions are more costly actions undertaken to meet the same set of safety problems at sites of specific hazard areas. These include bridge removals, alterations, and replacement, and rock cuts to improve channels. Removal of a few other miscellaneous obstructions are also included.

These safety actions all have one thing in common. The need for them is hard to measure and their effectiveness is difficult to evaluate. Based on prior work, a list of problem areas was developed where accidents had occurred in the past. These data are shown in Exhibit IV-3 of the K2 Report (Evaluation of the Present Navigation System). Two lists of candidate actions were developed to address these problem areas. These lists of actions provide a menu from which strategies could choose, based on the safety priorities specified for each strategy. The candidate safety actions for Strategies I, II, and III, and Strategy IV are shown in Exhibits IV-2 and IV-3 respectively.

(c) <u>Actions to Improve Linehaul Cost</u>

Every strategy had to adopt an attitude towards linehaul cost as a strategic priority. Since one particular strategy (Strategy IV) was designed to enhance water transportation by reducing linehaul costs, it was necessary to develop an appropriate set of actions to improve linehaul cost. Again, based on prior work and conclusions, the primary focus of actions was on channel dimensions. Both deep draft and shallow draft components of the navigation system were considered.

1. <u>Deepening Actions for Deep Draft Components</u>. A review of the data gathered from interviews conducted in Element D (Overview of the Transportation Industry), existing fleet characteristics, projected fleet characteristics, relative rates of growth in commerce of various commodities, available Corps studies and the location of existing ports with respect to markets led to several important conclusions for this class of action:

(a) Improved linehaul cost made available by more favorable channel dimensions is

most important to bulk commodities due to increasing use of deeper draft vessels.

(b) Since petroleum imports (a major bulk commodity moving in large vessels) was projected to decline, there would be no logical long range requirement to accommodate them with this action.

(c) Exports of bulk commodities (grain and coal) on the other hand are projected to grow substantially and would be aided by channel deepening at ports.

(d) A relatively small number of ports were logical candidates for this type of action, based on projected and historical patterns of internal movements of export commodities to ports, and the maximum export forecasts for the study period.

Based on these conclusions, actions to deepen port channels to 50' or more to accommodate projected growth in exports of these commodities were specified for the ports of Galveston, New Orleans, Mobile, Norfolk, and Baltimore. While these ports can logically be considered important candidates for such actions several caveats should be kept in mind with regards to port deepening.

West Coast ports such as Portland, Oregon were also considered for this action. Several of these ports already have controlling depths of 50' or more; e.g., Long Beach, California. Export shipments of coal however, were not projected to grow as rapidly for the West Coast as in other port ranges.

Other East Coast ports may also be candidates for port deepening to encourage these exports. The main reasons for not including them were the relatively small amounts of grain and coal export activity at these ports at this time, the lack of proximity to producing areas, poor rail service compared to other ports, and lack of space for large bulk commodity terminal facilities.

The constraints on Great Lakes shipping are well known and have been documented elsewhere, both in NWS work and other studies. The present draft constraint imposed

on foreign trade moving through the St. Lawrence Seaway is a maximum of 26.5'. While the Lakes are a major route for grain exports and will remain so, it is clear that any action or combination of actions to provide drafts of 50' or more for Great Lakes ports will be much more costly and complicated, involving not only ports but also locks. Close coordination with Canada would be essential.

One real constraint on the selection of ports for this action was the availability of cost data for the actions. Since NWS was not a project level study, cost estimates of these actions had to be drawn from previous or ongoing Corps analyses.

The whole point of this part of Strategy IV was not to recommend specific ports for deepening. Rather the intent was to show the general effects of such actions, including costs. Clearly, final selection of sites for port improvement as part of an export promotion program would have to be based on a more comprehensive analysis of all coasts and potential candidates.

2. <u>Channel Deepening Actions for Inland Waterways</u>. Major segments of the inland river system were reviewed as potential candidates for deepening actions. As a result, channel deepening was specified for three major river systems; the Mississippi River from Cairo, Illinois to Minneapolis, Minnesota; the Illinois Waterway; and the entire Ohio River from Cairo, Illinois to Pittsburgh, Pennsylvania.

Deepening has to be considered in light of the two basic types of river navigation systems. The first of these is the open river system where navigation depths are maintained by means of river training, dredging, and (in a few cases) reservoir releases. The second of these is the "canalized" system where depths are maintained by dams provided with locks to transit tows.

For open rivers the first concern is the amount of water available to sustain the necessary flows. Given sufficient water, then the concern is the means of establishing and maintaining the desired channel dimensions. Four open river segments were considered for deepening. Included in these were NWS Analytical Segments 4, 5 and 6, covering the Mississippi River from Cairo, Illinois to

Baton Rouge, Louisiana. These segments are even now being improved to the authorized 12-foot depth as part of the combined navigation and flood control program for these segments. The new depth is expected to be achieved by 1990. Therefore, since these ongoing activities will obtain the strategic objective, no further consideration was given to including the action in Strategy IV.

The fourth open river segment considered for deepening was NWS Analytical Segment 3, the Middle Mississippi from Cairo, Illinois to the mouth of the Missouri River. Based on prior Corps studies, increased dredging and river training was selected as the means of deepening this segment.

Canalized segments (also known as pooled or slack water systems) considered included the following NWS Analytical segments:

(a) Segment 1 -- Upper Mississippi from the Mouth of the Missouri to Minneapolis.

(b) Segment 9 -- Illinois Waterway (Illinois River and the lower 27 miles of the Des Plaines River).

(c) Segments 11 through 15 -- The entire Ohio River.

Water availability is not a constraint to deepening on these segments. Rather, the limitations are sill depths at locks. There are two means of obtaining greater depths in these systems. The first is increased dredging plus replacement of restrictive locks. The second is raising pool elevations. The first method was selected for these segments based upon concerns about the presumed relatively greater environmental impacts of increased pool elevations and uncertainties about the technical engineering feasibility of the modifications that might be required at some sites.

Increasing depths from the present 9' to 12' has been studied in detail for most of the segments involved. There is nothing particularly sacred about 12' other than this depth would make these segments compatible with the ultimate depth of the Lower Mississippi and the depth of most of the Gulf Intracoastal Waterway. A case might also be made that large increases in depth might be necessary

to induce private operators to make the large investments necessary to take advantage of the new depths.

In one case, the Upper Mississippi, a depth of 10' was selected, and it was specified only for Pool 12 and the pools below it. Dubuque, Iowa is located at the upper end of Pool 12. The shallower depth of 10' was specified because of greater concerns about potentially more adverse environmental consequences of a 12' channel. The 10' channel was extended only through Pool 12 because of the stricter environmental standards of the States of Wisconsin and Minnesota.

In all these deepening actions it is explicitly assumed that the same underkeel clearance is provided as in the present system. A detailed discussion of how these actions were evaluated for inland segments is contained in Appendix D.

3. Channel Widening for Inland Waterways. Channel depth is one dimension of a two dimensional concept that influences linehaul cost. The second dimension is channel width. Channel width, as a limiting factor on tow size, actually operates with channel bends to limit tow sizes. Most channels are adequate to accommodate two-way passage of tows in most places. However, based on previous work in Element K1 (Engineering Analysis of Waterways System), it was found that bend straightening by itself is not always possible or desirable. In any case, information on the locations of restrictive bends and the costs of modifying them was lacking.

Based in part on data gathered in other NWS elements, attention was focused on the Gulf Intracoastal Waterway and the Tombigbee-Warrior System as potential candidates for this type of action.[1] The Gulf Intracoastal Waterway System has some very restrictive channel dimensions. While tow lengths are fairly long, tows are

---

[1] The NWS Elements drawn on included Element D (Overview of the Transportation Industry), Element E/F (Review of National Defense, Emergency, and Safety Issues Affecting the Waterways), and Element K1 (Engineering Analysis Waterways Systems).

essentially restricted by channel dimensions (and the existing lock at Vermilion) to tow configurations of a single barge width. Many short reaches of this system were never completed to authorized dimensions. These restrictions are compensated for partly by greater depths, for that traffic which does not travel into shallower systems. Clearly, widening channels here would favorably affect linehaul cost. Unfortunately, there were no estimates available for the costs of widening this system, except for a few projects designed to obtain a uniform authorized width. Since these actions (widening in spots) would have no measurable effect on linehaul cost (measurable within the confines of NWS K2/L methodology), no channel widening actions were included in Strategy IV for Gulf Intracoastal Waterway segments.

Tow sizes are also limited on the Tombigbee-Warrior River System in Alabama. These smaller tow sizes affect not only linehaul cost, but also reduce lock throughput capacity at Demopolis and Coffeeville. This system (NWS Analytical Segment 35) is expected to experience substantial increases in traffic over the base period, much of which will be due to the completion of the Tennessee-Tombigbee Waterway. Because of this overall situation, the Tombigbee below the junction with the Warrior is a potential candidate for this type of action. Further, the Corps field offices involved also have this subject under study. Accordingly, cost estimates were available and the action was included in Strategy IV.

4. <u>Timing of Channel Related Actions to Improve Linehaul Cost</u>. Unlike other types of problems affecting capability, it is not clear how such actions would be timed lacking a comprehensive study. Lock capacity, for example, was explicitly estimated over time and compared to traffic over time. This comparison then gave a basis for stating when an action would be taken to relieve a lock capacity constraint. The timing of an action to improve linehaul cost, on the other hand, would logically be related to some linehaul cost objective or efficiency criterion. Rather than engage in this type of project level analysis, the bundle of actions described above would be implemented under Strategy IV by the year 1990 simply as directed actions to improve linehaul costs. It is important to emphasize that the bundle of actions specified under Strategy IV is by no means a definitive or limiting list of potential actions to improve linehaul cost. The intent was to specify a logical group of actions for which

supporting data could be assembled and evaluate them from a national perspective using the evaluation measures developed for NWS. All the channel-related actions which were included in Strategy IV are described more fully in Exhibit IV-4.

5. Lock Delays. Under Strategies I, II, and III, lock utilization must reach 95 percent before a major structural action is taken. This allows delays (and line-haul cost) to increase somewhat above historical levels before an action is taken. Therefore a logical component of a strategy designed to improve linehaul cost is to adopt a more generous lock capacity criterion. Accordingly major structural actions to increase lock capacity were taken when utilization reached 85 percent under Strategy IV. The result was that the same actions taken under Strategy III were taken earlier, and some additional actions to increase lock capacity were taken.

(d) Other Actions for Strategy IV

Two other actions were developed for Strategy IV which have less significant impacts on capability, but do represent actions consistent with an improved system. These are the performance of deferred maintenance dredging and the replacement of selected obsolete locks. Another action, season extension, was considered but not included.

1. Deferred Maintenance Dredging. During the last several years the Corps of Engineers has not continued the amount of dredging historically performed throughout the navigation system. There are several reasons for this; lack of funds, environmental constraints, lack of equipment, reduced levels of use of some projects etc. The volume of deferred dredging, expressed as an annual amount, was reported in the NWS inventory. Unfortunately, there is no basis for relating the dredging deferral to reduced capability. Nevertheless, performance of increased dredging over the baseline level would improve channel reliability, provide full authorized depth at existing little used minor projects, enhance safety, and improve service to recreational users. For all these reasons, the deferred dredging was included as an action for Strategy IV, using the inventory unit dredging costs and volumes as

reported in the Corps of Engineers NWS inventory. No evaluation measures were affected except for public expenditures. The amounts and unit costs in 1977 dollars of this activity are shown in Exhibit IV-5.

2. Replacement of Obsolete Locks. Locks in the present navigation system were subjected to an analysis of their condition relating to obsolescence. This analysis is contained in Appendix F of the K2 Report (Evaluation of the Present Navigation System). As part of a general upgrading of the navigation system under Strategy IV, all locks identified as obsolete were replaced or modified in the year 1990. The actions taken at obsolete locks are described in Exhibit IV-6.

3. Extension of Navigation Seasons. At the present time year round navigation is not available on two major shallow draft segments and parts of the deep draft system. It should be noted that, although navigation is limited by seasonal variations in some segments, seasons are not restricted by law. Authorizing documents and legislation for navigation projects typically specify channel dimensions and other project characteristics and conditions, but they are silent on seasonal limitations. Most projects incorporate design features that take into account seasonal considerations, and to the extent that a project is designed to function for only a part of the year, authorizations may be construed to implicitly incorporate such limitations. However, once a system or project is in place, there is no prohibition against attempting to operate it in a manner different than what was envisioned in the design. It then becomes a matter of technical considerations, levels of funding, and compliance with environmental requirements. Actions to extend navigation seasons over and above what is already being done as part of the "present system" were considered. The various segments involved are discussed in turn.

The Missouri River (NWS analysis Segment 10) has a normal navigation season of eight months. The season is extended in some years before the onset of winter if additional water in storage in the upstream reservoirs needs to be discharged to restore full flood control storage capacity. There are two limitations of this segment which prohibit year round navigation. First, there is not enough water available to support year round navigation on this particular segment which is almost unique in its

dependence on releases from reservoirs to maintain navigation depths. Second, concerns about public safety related to potential floods associated with ice jams dictate reduced releases during winter, even if enough water were available. Therefore, extension of the navigation season on the Missouri was excluded from all NWS strategies.

The Upper Mississippi above the junction with the Illinois Waterway (NWS Analysis Segment 1) is the other shallow draft waterway which does not operate year round. The normal navigation season is 9 months. Extension of the season on this segment has been studied by the Corps of Engineers. While season extension based on lock modification and ice breaking would appear to be technically possible, available information indicates that tow sizes would have to be reduced, incurring a linehaul cost penalty. Thus, while shippers might achieve some gains in terminal productivity and inventory management, there would seem to be economic penalties as well. Therefore, season extension for this segment was also excluded from Strategy IV.

The Great Lakes and St. Lawrence Seaway (NWS Reporting Region 16) also do not have year round navigation. This region includes NWS Analysis Segments 45 through 49 which are parts of the deep draft system. The navigation season on these segments has been extended by various means for several years now as a demonstration program. The program has been evaluated by the Corps and recommendations forwarded.

Concern in evaluating such an action in this region was that season extension would have a major effect in terms of attracting additional traffic with no positive effect on linehaul cost. Linehaul costs might even increase due to the greater difficulties in navigating in winter and the potential need for modifications to vessels. Since the primary thrust of Strategy IV was to find ways to improve linehaul cost, this action was not considered a logical candidate for Strategy IV.

Finally, navigation is impaired, or even eliminated altogether, at various coastal ports during winter, particularly in Alaska. Actions to extend the navigation season at these ports were not included for several reasons. First, the annual cargo throughput capacity at

these ports appears adequate even under these conditions. At least no bottlenecks were brought to the attention of the contractor team. Second, no data on seasonal restrictions at coastal ports was systematically developed in earlier phases of the total contractor effort because there was no perception of a problem. Third, no significant improvement in linehaul cost would be likely to accrue to season extension actions at ports compared to deepening. Fourth, some actions such as major ongoing ice breaking would be very costly for very marginal gains. Fifth, the data bases developed for NWS would not permit clear evaluation of such actions. For all these reasons, season extension at coastal ports was not included as an action for Strategy IV.

(e) Actions to Reduce Expenditures

Since two strategies operate with fixed budgets in a situation of rising costs it was necessary to formulate candidate expenditure reduction actions and decision rules for taking the actions. The actions and decision rules for taking these actions in Strategies I and II are discussed in turn.

1. Expenditure Reduction Actions for Strategy I. Since Strategy I gives the top priority to operating, maintaining, and rehabilitating the present system over construction of new facilities, the first action is to cease construction when funds are exhausted. As the real cost of "doing business" continues to increase, then various activities are simply deferred. There are three important points to keep in mind in reviewing the results of this strategy and the effects of expenditure reductions.

First (as will be discussed later in this section of this report), real cost increases for operating, maintaining, and rehabilitating the present system do not exceed the expenditure limit until the year 2000. Second, the characterization of "present policies" for this strategy suggests that deferral of expenditures without total withdrawal of federal support from the various projects constituting the present system would be a more likely action. Third, deferral of expenditures is more ambiguous in its effects since many projects will continue to be usable for many years well beyond the year 2003 cutoff

for this study even in the absence of normal maintenance and rehabilitation. Thus simple deferral of expenditures without specifying priorities is a logical action for this strategy consistent with present policies.

2. Expenditure Reduction Actions for Strategy II. The decision rules for funding priorities for Strategy II are much more complex than Strategy I. Additional bases for allocating funds were introduced which required a recasting of some basic inventory data and a simple means of setting priorities for funding. The purpose of the exercise was not to devise ultimate rules for allocating funds. Rather the purpose of the strategy was to illustrate the possible effects that a strategy oriented at re-allocating funds might have, taking into account various data and analytical limitations. The basic scheme was to devise a system of classifying the various components of the navigation system so as to establish spending priorities. The two levels of the classification scheme and the associated actions are discussed in turn.

There are many projects in the present system which have relatively little commercial significance and do not provide major increments to capability. However, it was not known how many of these projects were in the system, where they were located, nor how much of the total operations and maintenance cost they accounted for. Such projects would logically be the first candidates for withdrawal of federal support under a budget constraint. The NWS inventory contained the detailed information needed, but the data had never been sorted on this basis. With the assistance of the staff of the Institute for Water Resources a system for classifying all the subsegments in the inventory was devised and a revised data base was prepared based on the following definitions of side channels and minor harbors:

(a) Side channels were defined as projects or subsegments which carried no through traffic.

(b) Minor harbors were defined as harbors which served one million tons of commerce or less in 1976. Only those minor harbors shown in the NWS inventory to incur federal operations and maintenance costs were included for this action.

While the definition of minor harbors was very straightforward in its application, the classification of side channels was less clear in some cases and judgment was applied. It should also be pointed out the side channels by this definition included deep draft as well as shallow draft projects. Some channels which handled through traffic were also included as side channels when they were simply alternative routings with little traffic. No main stems of NWS Analysis Segments were classified as side channels. Also, most harbor data were broken down in the NWS inventory by specific projects and included side channels as defined here. In general harbors were considered as units and all channels retained unless available information suggested that a particular channel within a harbor could be considered a side channel.

It should be emphasized that the intent of the scheme was not to provide the ultimate classification scheme but to test the reasonableness of the idea and to obtain better information on the budgeting significance of side channels and minor harbors. A partial listing of side channels and minor harbors identified for this action is provided in Exhibit IV-7. The annual dredging volumes and nondredging operations and maintenance costs are sorted across these various activities in Appendices A and B. The results of the analysis are summarized in Table IV-2 below. The detailed breakdown of dredging volumes and other operations and maintenance expenses are shown in Appendices A and B respectively.

The second major classification scheme devised for Strategy II was to classify the shallow draft components of each NWS Analysis Segment into an "A", "B", or "C" category based upon a measure of cost effectiveness. This was not to be a measure of economic efficiency or the relative worthiness of projects since the entire integration process was designed to avoid passing judgment on individual projects. Accordingly no economic benefits were estimated nor were data gathered that would make such estimates possible. The purpose was simply to provide a reasonable basis for establishing funding priorities within this subsystem. Accordingly the cost effectiveness measured used was the sum of projected operations and maintenance expenses divided by ton miles of projected use. The results are shown in Table IV-3.

The classification scheme was examined for all four scenarios and all segments retained the same classification for all scenarios. The projected operations and

Table IV-2

Allocation of Corps of Engineers
Operations and Maintenance Activities

	Maintenance Dredging		Other Operations and Maintenance	Total Cost
	Annual Volume (100 c.y.)	Annual Cost ($1,000)(1)	($1,000)(1)	($1,000)(1)
Deep Draft				
Major Ports and Main Channels (including Locks)	1,779,786	127,895	24,465	152,360
Minor Ports	122,348	14,876	1,292	16,168
Side Channels	45,201	5,928	150	6,078
Subtotal	1,947,335	148,699	25,907	174,606
Shallow Draft				
Main channels	805,421	40,953	94,744	135,697
Side channels	137,060	9,397	5,386	14,783
Subtotal	942,481	50,350	100,130	150,480
TOTAL	2,889,816	199,049	126,037	325,086

Note: (1) 1977 dollars

SOURCE: Appendix A and Appendix B.

Table IV-3

Classification Scheme for Shallow Draft Waterways*

Class A		Class B		Class C	
Name	NWS Segment No.	Name	NWS Segment No.	Name	NWS Segment No.
Mississippi River, Illinois Waterway to Baton Rouge	2, 3, 4, 5, and 6	Missouri River	10	Kentucky River	19
Illinois Waterway	9	Allegheny River	17	Apalachicola, Chattahoochee, and Flint River	38
Ohio River	11, 12, 13, 14, and 15	Cumberland River	21	Alabama-Coosa Rivers	36
Monongahela River	16	Upper Columbia-Snake Waterway	51	Atlantic Intracoastal Waterway, Miami to Norfolk	39, 40, and 41
Kanawha River	18	Upper Mississippi River above Illinois River	1	Ouachita, Black, and Red Rivers	25
Green River	20	Gulf Intracoastal Waterway, Mobile to to St. Marks, Fla.	32	Arkansas and Verdigris Rivers(1)	24
Tennessee River	22 and 23			Old and Atchafalaya Rivers	26
Black Warrior and Mobile Harbor	35				
Tennessee-Tombigbee Waterway	37				
Gulf Intracoastal Waterway, Mobile to Brownsville	27, 28, 29, 30, and 31				

* Class A = Operations and Maintenance/ton miles less than 1.5 mills.

Class B = Operations and Maintenance/ton miles less than 5 mills and greater than or equal to 1.5 mills.

Class C = Operations and Maintenance/ton miles greater than 5 mills.

Note: (1) This segment subject to reclassification as a "B" segment based on higher levels of projected use and lower levels of maintenance dredging. This is discussed further in Section VI of this report.

maintenance cost was based on the methodology described later in this section. The classification scheme was calculated only for the year 2003 based on the premise that rational managers would make resource allocation decisions with long-term effects based on a long-term view of the world. The cost effectiveness of these segments were not calculated for any earlier years. Concerns were raised in the November 1980 public meetings about the classification of some specific segments, namely the Columbia-Snake and the Arkansas segments. The sensitivity of the classification of these two segments was examined in the Sensitivity Analysis step in the Integration Framework. The results of that analysis is discussed in detail in Section VI of this report.

One further action was also considered and was dropped from the set of actions for Strategy II. This action was the reduction of dredging on Class B segments short of withdrawal of all federal support. Reduced dredging would of course result in reduced depths and light loading of barges. A formula and data developed in Element K1 (Engineering Analysis of Waterways Systems) were used to relate reduced dredging to navigation depths and to calculate cost savings in turn. The formula is shown in Equation IV-1 below.

It should be noted that the formula cited in Equation IV-1 provided a basis (of unknown reliability) for analyzing dredging on rivers in more detail. However, no such relationship nor supporting data were available for conducting a similar analysis of the Great Lakes and the coastal ports due to the different hydrological systems involved. The state of the art regarding dredging simply is not advanced enough to permit such analysis. Thus, for purposes of NWS strategies, dredging became an all or nothing affair.

$$\text{IV-1} \qquad \left(\frac{D_1}{D_2}\right)^M = \frac{V_1}{V_2}$$

D = depth in feet
V = dredge volume in cubic yards

The values for the parameter "M" and the results of some preliminary calculations are shown in Table IV-4. The calculations in Table IV-4 show that the potential annual cost savings by reduced dredging on these segments would be minimal. They would not be enough to pay for a new lock chamber.

Table IV-4

Analysis of Dredging on Class B Shallow Draft Segments (1)

NWS Analysis Segment	Level of Activity	Morphology Factor	Depth Feet	Volume 100 c.y.	Unit Cost $/c.y. (2)	Total Cost $1,000	Potential Savings $1,000
1. Upper Mississippi	Baseline	3	9	27,291	1.003	2,737	
	Reduction of 1'	3	8	19,167	1.003	1,922	815
	Reduction of 2'	3	7	12,841	1.003	1,288	1,449
10. Missouri River	Baseline	3	8	48,484	0.829	4,019	
	Reduction of 1'	3	7	32,480	0.829	2,693	1,326
	Reduction of 2'	3	6	20,454	0.829	1,696	2,323
17. Allegheny River	Baseline	3	9	400	2.775	111	
	Reduction of 1'	3	8	281	2.775	78	33
	Reduction of 2'	3	7	188	2.775	52	59
21. Cumberland River	Baseline	3	9	892	2.029	181	
	Reduction of 1'	3	8	626	2.029	127	54
	Reduction of 2'	3	7	420	2.029	85	96
51. Upper Columbia Snake	Baseline			0			

Note: (1) Based on NWS Inventory data for the period 1973-77. See Appendix A to this document. Several errors were discovered in the data base which could affect the analysis. However, these errors were discovered too late in the study to incorporate the corrections. Appendix A documents the errors.

(2) Unit cost was not adjusted for reduced volumes.

SOURCES: NWS Inventory
Element K1, Engineering Analysis of Waterways System Capability

The total annual dredging expenditure for all Class B main channels during the base period was 7.7 million dollars. This was 3.7% of the total dredging budget during the period covered by the inventory. Even if all Class B dredging were eliminated the savings would not merit the sacrifice, particularly when the amount of money spent for deep draft ports, some of which handle fewer tons than some Class B segments, is considered.

Another important reason for not including this action was the adverse effect reduced dredging would have on lock tonnage throughput capacity. Significant reductions in dredging on major Class B Segments (such as the Upper Mississippi-Segment 1) and consequent light loadings would directly reduce lock capacity by the same amount. Not only would this trigger a need for costly structural actions to increase lock capacity on the Class B Segments where dredging was being reduced, but it would also reduce lock utilization on Class A Segments with high levels of traffic interaction. Thus, reduced dredging on a B segment to make money available to build a lock on an A segment could result in B segment locks becoming constrained at the same time that a constraint is being lifted elsewhere unnecessarily. This circular effect was reason enough to eliminate this action since such a chain of events would represent mismanagement.

Given that 68 percent of all dredging volumes and 21 percent of other operations and maintenance expenses are incurred for deep draft navigation, and taking all the data limitations into account, there simply was no basis for pursuing the logic of expenditure reduction actions under Strategy II any further without raising questions that could not be answered given the existing data constraints.

To summarize the important points regarding expenditure reduction decisions under Strategy II, two types of actions were developed. These are:

1. Withdrawal of federal support from side channels and minor harbors.

2. Withdrawal of federal support from Class C shallow draft segments.

These actions are taken only to keep expenditures within the fixed real budget limit after priority actions have been taken. The priorities for actions for Strategy II are shown in Table IV-5.

Table IV-5

Funding Priorities for Strategy II

Priority	Item
1.	Provide for Class A Waterways and Major Ports.
1a.	Provide operations, maintenance, and rehabilitation.
1b.	Provide increased lock capacity at 95 percent utilization if one million tons per year of grain and energy products are not accommodated in the year 2003.
1c.	Provide safety improvements in regions with growth.
2.	Provide for Class B Waterways with same subpriorities as Class A.
3.	Provide for Class C Waterways with same subpriorities as Class A.
4.	Provide operations and maintenance for minor ports and side channels.

COST COMPONENTS OF STRATEGIES

(a) Background

One problem that required almost as much attention as some of the other major technical problems of the integration process was the problem of organizing, projecting, and understanding the public costs of the navigation system. There are several reasons why the costs are important. First, the level of public expenditure associated

with strategies was clearly an important evaluation measure by itself. Second, two of the strategies eventually adopted (and two others dropped from consideration) were essentially resource allocation strategies. Therefore, strategies basing their decision rules on costs required a thorough treatment of costs. Third, one conclusion of the Element M (Analysis of Environmental Aspects of Waterways Navigation) analysis (supported by other findings in the research phase of NWS) was that the real costs of constructing and maintaining the navigation system had increased at a rate more rapid than the general price level, and was expected to continue to do so. Thus, the real costs of the navigation system were expected to rise over the time horizon of the study. All these factors dictated a thorough treatment of costs. The primary emphasis was on public expenditures made through the Corps of Engineers. The categories of costs utilized in the analysis are dredging, other operations and maintenance, construction, and rehabilitation. Expenditures by other public agencies were also identified, but were not included in the strategies.

(b) Real Costs Versus Nominal Costs

Real cost is an economic concept used to compare costs and prices over time. Using various statistical techniques, price data are adjusted so that changes in prices associated with general inflation are eliminated. Real prices are defined as the relationship of prices to one another that reflect the actual resource allocations being compared. Thus, once inflationary changes are removed from data, a commodity which has changed in price relative to other commodities is said to have changed in real terms.

For purposes of NWS all future costs are stated in real terms using 1977 as a base year. This is desirable for several reasons. First, it is consistent with the approach taken to forecasting projected use, all of which is based on analysis in real terms. Second, projections of real costs are less subject to wide variations over time. Any potential gain to the study in projecting 2003 costs in 2003 dollars would be minor compared to the very large range such a forecast would have. Finally, stating

future costs in real terms is consistent with Corps practices in normal planning studies and is readily understandable. Therefore, all the discussion that follows deals with real cost changes and how these were estimated.

(c) Sources of Cost Data

A variety of sources were consulted to address a variety of NWS analytical requirements. The information utilized was not drawn from a single consistent data base. The purpose was to develop reasonable information to support reasonable analysis. Where problems were found in the data bases, these were rectified to the extent possible based first upon the degree of precision actually required and second on the resources and time available to the contractor team. The significant findings regarding the validity of the data bases are reported where appropriate. However, it should be kept in mind that all the data reviews conducted as part of the integration effort cannot and should not be construed as any kind of audit of the Corps of Engineers. The level of accuracy required for an audit is related to the objectives of an audit and is much greater than the accuracy required for NWS. The level of accuracy of the cost information used in integration is likewise related to the level of accuracy of other components of integration and integration objectives.

(d) Operations and Maintenance

1. Dredging for Channel Maintenance. As shown in Table IV-2, dredging accounted for 62 percent of the total O&M costs during the period of time in which the inventory was taken. The cost of this activity has risen greatly in recent years due in part to the greater cost of disposal of dredged material. The dredging itself has not changed in cost as much as the cost of disposal due to the imposition of stricter environmental quality standards than had been observed in the past. This is consistent with the conclusion stated in Element M that the disposal of dredged material has greater environmental impacts than the act of dredging itself. Also, costs have increased recently due to fuel cost increase.

Since these trends are expected to continue it was desirable to review dredging costs and project them

into the future. Forecasts of future costs per cubic yard for dredging were developed for each NWS analysis segment based on fuel cost increases, increased cost of disposal, and gains in dredging efficiency through technological change.

Fuel cost increases were based on the compound rate of change for crude petroleum assumed in the scenarios. A single rate of increase namely four percent was used in this forecast effort. Roughly 20 percent of the dredging costs experienced during the period of time that the NWS inventory was compiled was for fuel. The real cost in 2003 of a dollar's worth of dredging in 1977 can be derived by equation IV-2.

IV-2

$$\text{Cost in Year 2003} = (1.04^{25} \times .2) + .8$$

Based on equation IV-2, the real cost of dredging will increase by 33.4 percent in the year 2003 due to projected real fuel cost increases alone.

The other factors affecting dredging cost were evaluated initially in terms of their ultimate effect on cost. For example, on many segments changes in disposal practices due to environmental concerns were projected to result in an ultimate doubling of costs. Changes in technology were treated similarly. Some costs were changed because costlier technology was expected to be used to address environmental concerns. In other cases dustpan dredges with lower labor costs were projected to be substituted for existing dredges of other types resulting in cost savings. Reductions in dredging volume were considered but were generally excluded from this process because of an inability to project changes in volume. For one part of the system, the Mississippi River between Cairo, Illinois and Baton Rouge, a cost reduction resulting from technological change combined with reduced volumes was projected. (Later in the integration process forecasts of future dredging volumes were made available from some field offices for some segments and these are treated in the sensitivity analysis.) Also, some NWS segments were broken down into subsegments for purposes of cost forecasting where there was a reason to do so and the available data supported the analysis.

All these factors, fuel, technological change, and environmental restrictions were expressed in terms of the ultimate percentage change in total cost by the year 2003. These percentage changes were then combined multiplicatively to arrive at a single projected percentage change in total cost for each NWS segment. The compound growth rate (r) in cost for each segment was then computed with equation IV-3.

IV-3
$$\text{Unit Cost in 2003} = (1+r)^{25}$$

For example, the unit cost of dredging in Lake Erie (NWS Segment 46) was projected to cost 60 percent more due to increased disposal costs just to comply with existing environmental policies by the year 2003. Also, costs were projected to decline 10 percent due to technological change in this segment. These changes, combined with fuel cost changes result in a 92.1 percent increase in dredging cost (1.6 x 1.334 x .9 = 1.921) for this segment. This future cost represents a compound rate of increase of 2.65 percent per annum (after rounding).

IV-4
$$1.921 = (1.0265)^{25}$$

The purpose in computing these compound growth rates was to provide a means of estimating the dredging costs for intervening years. The growth rate was then applied to the average unit costs per cubic yard derived from the NWS inventory for the base year to project real unit costs for all years between 1977 and 2003. Dredge volumes were not changed over time except for sensitivity analyses for a few segments. The compound growth rates of unit dredging costs for all NWS Analysis Segments are shown in Exhibit IV-8.

Another factor that could possibly result in higher dredging costs, according to Corps sources, is the switching to contractor dredging. The anticipated need for more frequent surveys could increase costs. On the other hand, relying on competitive bidding could help hold down cost increases.

One other activity was also undertaken during integration with regards to dredging costs. Some NWS analysis segments appeared to have unusually high unit

costs for dredging reported in the NWS inventory. The San Francisco Bay Area (Segment 55) in particular accounted for 2 percent the total volume in cubic yards of all federal dredging and 47 percent of the total federal dredging expenditure for all segments. This segment and others were rechecked and corrected data developed. The result was that a total federal expense of $304 million annually for federal dredging reported in the NWS inventory was reduced to $206 million annually.

2. Other Operations and Maintenance. This category of costs includes all costs for operations and maintenance of Corps projects allocated to navigation. These costs cover activities such as lock and dam operation including utilities and crew wages, and routine maintenance of navigation structures including such items as locks, dams, dikes, revetments, and breakwaters.

Based upon the conclusions of prior work in other NWS elements, it was decided that no attempt would be made to project real changes in these costs. First of all, these activities were not found to have any significant environmental impacts. Therefore, there was no reason to expect changes in costs to deal with these concerns. Second, the grouping of "other operations and maintenance" includes a wide variety of activities. The relative importance of energy costs, the primary economic force driving other real cost changes, as a component cost for these activities simply is not known. Thus there was no basis for projecting this particular impact on these costs.

Finally, a large share of these costs are incurred at locks. Many of these activities at locks are labor intensive and there is no basis for projecting a rate of growth in real wages for lock crews different from the general wage level. In fact, federal compensation policies are designed to hold this relationship stable. While lock crews may increase in size at some sites as traffic increases, many of the minor structural and nonstructural measures at locks incorporated into the K2 capacity analysis will also increase lock crew productivity. Thus there is no basis for adjusting "other O&M" at locks.

The final conclusion was that it would be most reasonable to project "other O&M" costs at a constant level based on constant real costs.

One other point needs to be made about these costs. Where navigation is part of a multipurpose development scheme within a segment, some share of the joint costs of the development is allocated to navigation and these costs are included here. However, it must be recognized that these cost allocations often reflect formulas devised at the time of construction and may not reflect the real opportunity costs of navigation. To the extent that actual decisions, such as cost sharing, are based on these allocations, the outcomes may be distorted unless a fresh look is taken at some of these costs.

(e) Construction

Another issue that was examined was the trend in the real costs of construction. There were two bases for considering trends in this component of costs. First, the view has been widely held for some time that construction costs tend to rise more rapidly than the general price level. Second, construction activities are widely viewed as having significant environmental impacts. This view was confirmed by the Element M (Analysis of Environmental Aspects of Waterway Navigation) research. Indeed, many ongoing Corps projects have incorporated costly mitigation measures and/or adopted more costly techniques to avoid or minimize environmental damage. A good example is the use of draft animals rather than heavy equipment for certain clearing and grubbing activities in the Tennessee-Tombigbee Waterway Project.

All these considerations led to a review of various statistical indexes. The results of this review are summarized in Table IV-6.

The first two indexes, the Wholesale Price Index (now called the Producers Prices Index) and the GNP Deflator, are measures of the general price level of the economy as a whole. The next five indexes in the table (Portland Cement; Finished Steel for Construction; Sand, Gravel and Crushed Stone; Construction Equipment; and Hourly Earnings of Construction Labor) are all indexes of selected components of construction costs compiled by the U.S. Bureau of Labor Statistics which are relevant to the type of heavy construction involved in most Corps projects. The

Table IV-6

Relative Rates of Change of Selected Price Indexes

Source	Wholesale Prices	GNP Deflator	Cement	Construction Steel	Aggregates	Equipment	Hourly Earnings in Construction	Construction Cost Index
	1	2	1	1	1	1	1	3
Base Year of Index	1967	1972	1967	1967	1967	1967	1967	1913
Values of Index								
1967	100.0	79.0	100.0	100.0	100.0	100.0	100.0	1,070
1979	235.6	165.5	283.3	279.5	207.1	256.2	222.0	3,003
Compound Rate of Change	7.4%	6.4	9.1	8.9	6.3	8.2	6.9	9.0

SOURCES:

1. Bureau of Labor Statistics (BLS)
2. Bureau of Economic Analysis (BEA)
3. Engineering News Record (ENR)

final index is the Construction Cost Index compiled privately by the publication Engineering News Record. The compound rates of growth shown in Table IV-6 were estimated by solving equation IV-5 shown below:

IV-5

$$\text{1979 Value} = \text{1967 Value} \times (1+M)^{12}$$

The ENR Construction Cost index attempts to represent changes in construction costs by aggregating trends for various materials and labor. There is no comparable index published by a public agency which purports to combine the various components of construction cost. While the ENR index may overstate the rate of change of construction costs due to the failure to recognize productivity gains for construction labor, the ENR index is not the only index examined here which has increased more rapidly than the two general indexes. The BLS indexes for cement, construction steel, and equipment, as well as the ENR index have all increased more rapidly than the two general indexes.

Construction aggregates, as reported by the Bureau of Labor Statistics, have gained in price more slowly than the general indexes during the period shown. There is reason to believe that this rate of increase is understated. The price information gathered by the BLS is "F.O.B. mill or distribution center" and does not include transportation to construction sites. This transportation can often double the ultimate cost to a job and has been subject to real cost pressures in recent years because it is energy intensive. Thus the rate of change for the real cost of aggregates is probably higher than that shown in Table IV-6.

Wages of construction labor have been under pressure in recent years due to adverse construction market conditions and increased competition between union and nonunion workers. This probably accounts for the fact that labor costs have lagged three of the other four construction cost components shown in Table IV-6 in the rate of change over the period covered. Nevertheless the rate of change of this index falls between the rates of change of the two general indexes. Also, the Engineering News Record reports

that wages for common laborers have risen more rapidly than for the various skilled trades. Since heavy construction activities typical of Corps projects use a higher percentage of unskilled workers, the rate of increase for the BLS Hourly Earnings Index probably understates the rate of increase for Corps projects.

The review of these indexes led to the conclusion that real costs of construction probably do increase faster than the general price level. For purposes of NWS an annual compound growth rate of 1.25 percent was adopted to project future real cost increases.

This rate of growth was applied to the estimates of "first costs" shown in Exhibits IV-1, IV-2, IV-3 and IV-4, and IV-6 for all structural actions at the time that an action was taken under the decision rules of a strategy. The basic estimates of first costs for actions were developed using existing Corps studies and the costing methodology developed in Element K1 (Engineering Analysis of Waterways Systems).

(f) Rehabilitation of Navigation Structures

Navigation structures like other structures or machinery occasionally need major repairs. Routine maintenance is captured in the annual "other O&M" expense category. However, this does not include major repair and overhaul activities that occur less frequently than annually. Such actions would include such things as replacing mitre gates on locks, resurfacing lock walls, and replacing pilings in dikes and jetties.

One thing distinguishes rehabilitation activities from other types of actions at locks included in NWS strategies. While other types of actions are designed to meet needs which are defined as shortfalls in capability, rehabilitation actions do not meet shortfalls. Rather, rehabilitation actions are taken to preserve existing capabilities rather than to change them.

The problem in formulating rehabilitation actions was that there was no basis for predicting the need for specific rehabilitation actions. The need for such actions are developed in actuality by periodic surveys of structures by Corps field personnel. These reconnaissance surveys result in more detailed analyses and specific recommendations for funding. NWS could not replicate this process of identifying existing rehabilitation requirements, much less future requirements, on a structure by structure basis.

Also, the available data on rehabilitation did not provide an adequate guide for developing site specific actions. This is partly a result of the Corps preference in the past for total replacement of aging facilities which were generating additional rehabilitation requirements. Thus, rehabilitation has been minimized in the past and, until recent years, not even reported as a separate activity.

The analysis of the present system (K2) explicitly assumed "adequate maintenance and rehabilitation". Since individual rehabilitation actions could not be predicted (compared to the need for actions to increase lock capacity) an alternative approach was needed. The approach taken was to estimate the frequency of actions based on the available information, relate actions to costs based on lock characteristics, and project aggregate funding requirements for the present system at the NWS analytical segment level, without saying where, when, or how the money would be spent. The result was a series of "average annual" funding forecasts expressed in 1977 dollars.

This projection incorporates two parts. The first part is the most complex, based on published engineering analyses of seven locks. A model of lock rehabilitation costs was developed from these studies. Factors were also developed to adjust these expenditures for the age, size, and lift of lock chambers. All these factors are applied to the locks of the present system over time to project rehabilitation expenditures for locks.

The second part of the analysis concerned segments without locks. The NWS inventory indicated that rehabilitation activities did take place in segments without locks, although the level of expense was lower. The approach taken was to project a constant level of these expenses representing a constant level of activity into the future, allocated among segments based on the historical first costs of the system.

Since rehabilitation actions are essentially construction activities, often done under contract, the same real cost escalator developed for structural actions was also applied to rehabilitation. Thus rehabilitation expenses grow over time as the locks grow older and as the real cost of actions increases.

Rehabilitation actions at locks were also adjusted when old lock chambers were replaced. When an existing chamber was removed from service as a result of a major structural action to increase lock capacity or as part of a channel deepening action, average annual rehabilitation expenditures for the existing chamber were ceased.

One major difficulty was reconciling the rehabilitation expenditure projections with the data in the NWS inventory. The integration methodology generated expenditures of only $37 million annually in 1977 for the present system while the inventory reported an annual expenditure of $94 million annually. Closer scrutiny of the inventory revealed some interesting findings. The most significant finding was that 51% of the national total, namely $48 million had been reported for one NWS analysis segment, the Upper Mississippi (Segment 1). Upon investigation it was learned that several years' of expenditures had been reported as an average annual figure.

The second finding was that the Lake Michigan Segment (Segment 48) showed an annual figure of $9 million, which was 10% of the total, even though this segment has no locks. This also was investigated. It was found that the expenditure was a one time expenditure to construct diked disposal areas for dredged material.

Although the inventory printouts label the data as rehabilitation, the coding instructions called for identification of rehabilitation or "unusual maintenance expenditures". Since construction of these disposal areas was unusual and not necessarily expected to recur, the person responsible for the coding had logically classified the expense in this record.

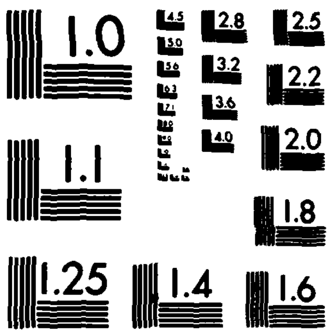
The NWS inventory of rehabilitation expenses clearly overstates these costs and any attempt to reconcile the projections with the inventory would require reconstructing the entire inventory. Given the problems discovered in this part of the inventory it was decided to rely on the procedure described above.

There are two possibly significant shortcomings in the approach to rehabilitation taken in NWS. The first of these relates to the reliability of navigation structures. Even when major actions are taken there is no guarantee that an old structure will not fail in the future. The state of the art of engineering simply does not permit reliable forecasts of structural failures. The best evidence of this was the debate about the rehabilitation alternatives considered as part of the Locks and Dam 26 controversey. No experts employed or retained by any party to the dispute were able to state definitively that major rehabilitation would in fact guarantee the integrity of the existing facility for another 50 years. This inability to predict structural failure is one of the main reasons that the Corps has historically preferred replacement to continued rehabilitation.

Another shortcoming of the analysis is that the adverse long term effects of periodic and increasing disruptions of commerce resulting from temporary closures of locks for major rehabilitation actions have not been analyzed. If these temporary disruptions become significant over time, shippers may become less willing to rely on water transportation and the effectiveness of the navigation system as part of the total transportation system may be impaired.

AD-A127 294 EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION 2/4
(U) KEARNEY (A T) INC CHICAGO ILL J EGAN ET AL. SEP 81
DACW72-79-C-0003

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(g) Costs for Completing The Present System

Various ongoing construction projects have been incorporated into the assumed NWS "present system". While these activities were not modified in any strategies, the costs nevertheless remain important as part of the total expenditure over the time horizon of the study. Budgetary submissions were reviewed to identify expenditures between 1977 and 1979. The projected costs to complete these projects were spread evenly over the years between 1980 and the planned completion date, and the real cost escalator for construction was applied.

(h) Establishing Real Budget Levels

Developing a budget for the integration phase of NWS was actually a parallel effort with the various cost analyses described above. The first key question was to determine the trends in recent years of Corps expenditure in real terms. A recent staff memorandum on this subject was provided and is summarized in Table IV-7. The time series in Table IV-7 for real appropriations is based on the ENR construction cost index for contracts and a personnel cost index for all other appropriations.

Two interesting conclusions are suggested by Table IV-7.

1. While nominal total appropriations have more than doubled between 1967 and 1980, the real value of appropriations has remained constant or declined.

2. The share of Operations and Maintenance, both in nominal and real terms has increased, just as the share of construction has decreased.

There remained the problem of putting together a reasonable navigation budget since the numbers cited in Table IV-7 were for all Corps activities including flood control, hydropower, etc. The budget for Operations and Maintenance, including dredging, based on the NWS inventory.

Table IV-7

Trends in Corps of Engineers Budgets[1]

Item	General Investigations		Construction General		Operations and Maintenance		General Expense		Flood Control MRT		All Appropriations	
Fiscal Year	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real
1967	32	32	966	966	179	179	18	18	87	87	1,293	1,293
1968	34	31	968	922	193	191	20	19	87	84	1,305	1,249
1969	30	25	863	778	227	209	22	18	70	64	1,246	1,124
1970	41	31	712	587	262	223	25	19	81	66	1,157	955
1971	39	28	851	650	302	235	28	20	84	64	1,310	1,002
1972	51	33	1,025	704	389	275	30	20	86	59	1,589	1,097
1973	58	35	1,204	727	407	258	32	20	112	66	1,952	1,190
1974	56	32	874	503	427	259	35	22	265	149	1,770	1,031
1975	65	35	966	502	495	268	40	24	120	61	1,757	927
1976	67	34	1,237	600	582	291	44	23	205	101	2,183	1,073
1977	72	32	1,437	621	668	300	49	25	231	100	2,492	1,094
1978	107	47	1,538	621	769	328	60	28	253	101	2,784	1,148
1979	138	56	1,344	508	833	344	69	31	223	86	2,735[2]	1,075

Notes: (1) Real figures are 1965 dollars.

(2) Reflects reduction of $55.4 million which were unobligated at end of FY 1979 and reappropriated to the Construction, General account in FY 1980.

Source: Memo, DAEN-CWB-H.

Construction expenditures were based on data from the Annual Report of the Chief of Engineers on Civil Works Activities. This document summarizes expenditures for "new work" by general activity categories. The expenditures for new work for navigation over time are summarized in Table IV-8.

Based on a review of the navigation construction appropriations during the decade of the 70's, a figure of $253 million was selected as a representative annual navigation construction budget.

The fixed real budget in 1977 dollars for Strategies I and II then includes the following items:

	Millions of $
Dredging	206
Other Operations and Maintenance	126
Construction	253
Total	585

This budget was used only in Strategies I and II. Also, expenditures projected to operate, maintain, rehabilitate, and complete the present system were not restricted to this limit prior to 1995. However, the completion of the present system was assumed to have a budgetary effect on Strategies I and II in that no optional major structural actions were allowed to be initiated prior to 1991 because it was assumed that completion of the present system would use all available funds.

(i) Expenditures by Non-Federal Public Agencies

Although the main focus of NWS has been the activities of the Corps of Engineers, other public agencies are also involved in providing the basic capability of the navigation system. None of the expenditures identified

Table IV-8

Appropriations for Navigation Construction

Year	Millions of $ 1/
1969	219
1970	199
1971	185
1972	212
1973	264
1974	193
1975	221
1976 2/	358
1977	261
1978	357
1979	395

NOTES: 1/ All figures are current dollars.

2/ 1976 includes the transition quarter when the schedule for the federal fiscal year was shifted. Annualized appropriations would be 4/5 of 358 or 286.

SOURCE: Annual Report of the Chief of Engineers on Civil Works Activities, various years.

for these agencies have been included in the budget developed for Strategies I and II, nor are these expenditures included in the evaluation measures for strategies. The discussion here is for informational purposes only.

1. Port Authorities. Port authorities are political entities created by states to construct, operate, and maintain port facilities and promote the use of ports. The level of involvement of authorities in providing infrastructure varies widely. Most of these activities are self financing, relying on user charges for revenues to cover operating expenses and retire debt. A survey by the Maritime Administration revealed that between 1946 and 1978 $5 billion was spent on piers and wharfs. Annual revenues and expenditures are not available.

2. New York State Waterways. The NWS inventory shows an annual dredging volume of 1,929,100 cubic yards and a total dredging expenditure of $15,530,000 and no expenditures for "Other O&M" by the State of New York. If these figures are accurate the unit cost of dredging was $8.05 per cubic yard for this NWS segment (Segment 43). These expenses were not included in the baseline activities and budgets analyzed in these documents.

3. St. Lawrence Seaway Corporation. The St. Lawrence Seaway Corporation is a federally chartered corporation established to construct, develop, operate, and maintain that part of the St. Lawrence Seaway within the territorial limits of the United States. The agency owns and operates two locks (Snell and Eisenhower) on the St. Lawrence River portion of the Seaway (NWS Segment 45) and maintains various parts of the channel within American borders. The corporation is self financing through tolls collected for use of its facilities. In 1977 the corporation had revenues of $8.6 million and operating expenses $5.2 million. All revenues and expenses associated with both the Canadian and United States facilities were excluded from the baseline budget and the evaluation measures.

4. United States Coast Guard. The annual Coast Guard budget has ranged between $900 million and $1 billion between 1978 and 1980. The 1978 appropriation was $924 million while outlays were $897 million. A large share of this expenditure supports activities other than commercial navigation. For example, approximately 28% of this expenditure was for search and rescue which benefited recreation, off shore industry (minerals and fishing), and transportation. However, the available data provides no basis for allocating these costs among beneficiaries.

Candidate Major Structural
Actions to Increase Lock Capacity(1)

NWS Region	NWS Segment	River/Waterway	Lock Name	Type of Action: Construct an Additional Chamber	Type of Action: Replace an Existing Chamber	Dimensions of New Chambers: Width (feet)	Dimensions of New Chambers: Length (feet)	First Cost(2) ($1,000)	Increase in Annual O&M Cost(2) ($1,000)
Upper Mississippi	Upper Mississippi	Mississippi R., Minneapolis to mouth of Illinois River	L&D 25		X	110	1,200	90,000	0
			L&D 24		X	110	1,200	90,000	0
			L&D 22		X	110	1,200	90,000	0
			L&D 21		X	110	1,200	90,000	0
			L&D 20		X	110	1,200	90,000	0
			L&D 19	X		110	1,200	65,000	90
			L&D 18		X	110	1,200	90,000	0
			L&D 17		X	110	1,200	90,000	0
			L&D 16		X	110	1,200	90,000	0
			L&D 15		X	110	1,200	90,000	0
			L&D 2		X	110	1,200	90,000	0
Lower Upper Mississippi	Lower Upper Mississippi	Mississippi R., Illinois R. to Missouri R.	L&D 26	X		110	1,200	97,000	200
	Middle Mississippi	Mississippi R., Missouri R. to Ohio R. (Chain of Rocks Canal)	L&D 27	X		110	1,200	305,000	200
Baton Rouge to Gulf	Baton Rouge - Morgan City Bypass	Port Allen Route	Port Allen	X		110	1,200	150,000	190
Illinois Waterway	Illinois Waterway	Illinois R.	LaGrange		X	110	1,200	77,000	0
			Peoria		X	110	1,200	79,000	0
			Starved Rock		X	110	1,200	77,000	0
			Marseilles		X	110	1,200	85,000	0
			Dresden Island		X	110	1,200	63,000	0
		Des Plaines R.	Brandon Road		X	110	1,200	63,000	0
		Chicago Sanitary and Ship Canal	Lockport		X	110	1,200	63,000	0

Candidate Major Structural
Actions to Increase Lock Capacity(1)

NWS Region	NWS Segment	River/Waterway	Lock Name	Type of Action: Construct an Additional Chamber	Type of Action: Replace an Existing Chamber	Dimensions of New Chambers: Width (feet)	Dimensions of New Chambers: Length (feet)	First Cost(2) ($1,000)	Increase in Annual O&M Cost(2) ($1,000)
Ohio River	Upper Ohio	Ohio River, confluence of Allegheny and Monongahela Rivers to Kanawha River	Emsworth		X	110	1,200	100,000	60
			Dashields		X	110	1,200	90,000	60
			Montgomery		X	110	1,200	200,000	60
	Middle Ohio	Ohio River, Kanawha River to Kentucky River	Gallipolis		X(3)	110	1,200	205,000	60
						110	600		
			Greenup	X		110	1,200	69,000	200
			Meldahl	X		110	1,200	125,000	200
			Markland	X		110	1,200	125,000	200
	Lower Ohio Three	Ohio River, Kentucky River to Green River	McAlpine	X		110	1,200	125,000	200
			Cannelton	X		110	1,200	110,000	200
			Newburgh	X		110	1,200	120,000	200
	Lower Ohio Two	Ohio River, Green River to Tennessee River	Uniontown	X		110	1,200	105,000	200
			Smithland	X		110	1,200	105,000	200

Candidate Major Structural
Actions to Increase Lock Capacity(1)

				Type of Action		Dimensions of New Chambers			Increase
NWS Region	NWS Segment	River/Waterway	Lock Name	Construct an Additional Chamber	Replace an Existing Chamber	Width (feet)	Length (feet)	First Cost(2) ($1,000)	in Annual O&M Cost(2) ($1,000)
Ohio River	Monongahela River	Monongahela River	L&D 2		X	110	720	45,000	0
			L&D 3		X	110	720	45,000	0
			L&D 4		X	110	720	45,000	0
			L&D 7		X	110	720	45,000	0
	Kanawha River	Kanawha River	Winfield		X	110	600	50,000	0
	Green River	Green River	L&D 1	X		110	600	50,000	100
			L&D 2	X		110	600	50,000	100
Tennessee River	Lower Tennessee	Tennessee R.	Kentucky		X	110	1,200	160,000	0
Gulf Coast West	GIWW West One	Gulf Intra-coastal Water-way	Harvey		X	110	1,200	150,000	60
			Algiers		X	110	1,200	150,000	100
Gulf Coast East	GIWW East One	Inner Harbor Navigation Canal	Inner Harbor	X(4)		110	1,200	70,000	200
Mobile River and Tributaries	Black Warrior-Mobile Harbor	Warrior River	Bankhead	X		110	600	70,000	100
			Holt	X		110	600	70,000	100
			Oliver	X		110	600	70,000	100
			Warrior	X		110	600	70,000	100
		Tombigbee River	Demopolis	X		110	600	70,000	100
			Coffeeville	X		110	600	70,000	100

Candidate Major Structural
Actions to Increase Lock Capacity(1)

NWS Region	NWS Segment	River/Waterway	Lock Name	Type of Action: Construct an Additional Chamber	Type of Action: Replace an Existing Chamber	Dimensions of New Chambers: Width (feet)	Dimensions of New Chambers: Length (feet)	First Cost(2) ($1,000)	Increase in Amount O&M Cost(2) ($1,000)
Great Lakes St. Lawrence Seaway - New York	Lake Ontario and St. Lawrence Seaway	St. Lawrence River	St. Lambert	X		130	1,200	(5)	
			Cote Ste. Cathrine	X		130	1,200		
			Lower Beauharnois	X		130	1,200		
			Upper Beauharnois	X		130	1,200		
			Snell	X		130	1,200		
			Eisenhower	X		130	1,200		
			Iroquois	X		130	1,200		
		Welland Canal	1	X		130	1,200	(6)	
			2	X		130	1,200		
			3	X		130	1,200		
			7	X		130	1,200		
			8	X		130	1,200		
	Lake Huron	St. Mary's R.	Sault Ste. Marie	X		130	1,200	102,000	190
Columbia-Snake Waterway-Willamette River	Upper Columbia-	Columbia R.	Bonneville		X	86	675	85,000	90

SOURCES: NWS Working Papers, IWR Letter dated 22 May, 1981.

Notes: (1) These are not recommended actions nor were these actions all actually taken under the application of any particular strategy. The intent of the exhibit is to display the individual actions formulated for subsequent use. The locks included were based upon utilization levels realized in the Element K2 analysis.

(2) Costs expressed in 1977 dollars.

(3) This action incorporates a bypass canal with a new 100' x 1,200' chamber and a new 110' x 600' chamber.

(4) Simply replacing the existing chamber with a larger chamber would not substantially increase capacity at this site due to the peculiar nature of the traffic. Therefore a new larger chamber is provided to increase capacity and the old chamber is retained to continue to serve traffic that can use it effectively.

(5) Cost for increasing capacity of all St. Lawrence River Locks is estimated at $2,000,000,000 in 1981 dollars.

(6) The action specified for NWS purposes was the additions of chambers at five site. The Canadian government plan for improvements entails construction of an entirely new canal costing approximately $2,000,000,000 in 1981 dollars.

CANDIDATE SAFETY ACTIONS FOR STRATEGIES I-III(1)

Region	Segment	New or Enhanced Vessel Traffic Service Center(2)	Minor Structural Actions Bridges(3)	Minor Structural Actions Locks(4)	Minor Structural Actions Channels(5)	Construction Costs ($000s)(6)	Annual Operating Costs ($000s)(6)
Upper Mississippi	Upper Mississippi	-	8	1	1	10,000	-
? w upper Mississippi	Middle Mississippi	-	8	-	1	17,000	-
Lo..er Mississippi	Lower Middle Mississippi	-	4	-	-	8,000	-
	Upper Lower Mississippi	-	3	-	2	7,000	-
Bato. .ge to Gulf	Baton Rouge to New Orleans	1	2	-	2	6,000	500
	New Orleans to Gulf	1	2	-	1	5,000	500
	Old and Atchafalaya Rivers	-	3	-	-	3,000	-
	Baton Rouge to Morgan City	1	1	-	-	1,000	500
Illinois Waterway	Illinois Waterway	1	17	-	2	24,000	500
Ohio River	Upper Ohio	2	2	4	-	6,000	1,000
	Middle Ohio	1	3	3	-	6,000	500
	Lower Ohio-Three	2	1	1	-	2,000	1,000
	Lower Ohio-One	-	-	-	1	1,000	-
	Monongahela	1	-	-	-	-	500
	Green	-	3	-	-	3,000	-
	Cumberland	-	3	-	-	3,000	-
Tennessee River	Upper Tennessee	2	1	-	-	1,000	1,000
	Lower Tennessee	-	1	-	-	2,000	-

CANDIDATE SAFETY ACTIONS FOR STRATEGIES I-III(1)
(Continued)

Region	Segment	New or Enhanced Vessel Traffic Service Centers(2)	Minor Structural Actions Bridges(3)	Locks(4)	Channels(5)	Construction Costs ($000s)(6)	Annual Operating Costs ($000s)(6)
Gulf Coast West	New Orleans to Calcasieu River	2	16	-	-	16,00	1,000
	Calcasieu to Corpus Christi	1	12	2	-	16,000	500
	Houston Ship Channel	(7)	-	-	1	1,000	-
Gulf Coast East	New Orleans to Mobile Bay	1	5	-	2	12,000	500
	Mobile Bay to St. Marks, Fla.	1	-	-	-	-	1,000
Mobile River and Tributaries	Black Warrior-Mobile Harbor	-	10	-	3	14,000	-
South Atlantic Coast	Florida/Georgia Coast	2	3	-	-	6,000	1,500
Middle Atlantic Coast	Chesapeake and Delaware River	2	8	-	-	16,000	2,000
	New Jersey-New York Coast	-	2	-	-	4,000	-
North Atlantic Coast	North Atlantic Coast	-	5	-	-	10,000	-
Great Lakes/St. Lawrence Seaway	Lake Ontario and Seaway	1	-	-	1	5,000	500
	Lake Erie	-	16	-	-	32,000	-
	Lake Huron	1	5	-	-	10,000	1,000
	Lake Michigan	-	4	-	-	8,000	-
	Lake Superior	-	3	-	-	6,000	-

CANDIDATE SAFETY ACTIONS FOR STRATEGIES I-III(1)
(Continued)

Region	Segment	New or Enhanced Vessel Traffic Service Centers(2)	Minor Structural Actions: Bridges(3)	Minor Structural Actions: Locks(4)	Minor Structural Actions: Channels(5)	Construction Costs ($000s)(6)	Annual Operating Costs ($000s)(6)
Washington/Oregon Coast	Puget Sound	1	6	-	-	11,000	1,000
Columbia-Snake W.	Upper Columbia-Snake	-	-	1	-	1,000	-
	Lower Columbia-Snake	1	1	-	-	2,000	500
California Coast	San Francisco Bay Area	1	2	-	-	4,000	500
	Central/South California	1	-	-	-	-	1,000
Alaska	Southeast	1	-	-	-	-	300
Hawaii	Hawaii	-	1	-	-	2,000	-
Total		28	161	17	17	281,000	17,500

Notes: (1) Actions taken in regions with traffic growth of 10,000,000 tons or more by 2003. These actions would be used for Strategies I, II, and III.

(2) A dash indicates no change from the present level of services.

(3) Includes such actions as installation of fenders, radar transponders, and radar reflectors.

(4) Includes actions at other waterway structures. Actions at locks include installation of mooring cells and/or guidewalls.

(5) Placement of aids to navigation.

(6) Costs expressed in 1977 dollars.

(7) Part of VTS for Gulf Intracoastal Waterway.

EXHIBIT IV-3
Page 1 of 3

CANDIDATE SAFETY ACTIONS FOR STRATEGY IV(1)

Region	Segment	New or Enhanced Vessel Traffic Service Centers(2)	Minor Structural Actions: Bridges(3)	Minor Structural Actions: Locks(4)	Minor Structural Actions: Channels(5)	Major Structural Actions: Bridge Removals	Major Structural Actions: Bridge Alterations	Major Structural Actions: Bridge Replacements	Major Structural Actions: Rock Cuts	Construction (Costs ($000s))(6)	Annual Operating Costs ($000s)(6)
Upper Mississippi	Upper Mississippi	-	5	1	-	2	2	-	1	65,000	-
Lower Upper Mississippi	Middle Mississippi	-	8	-	-	-	-	-	-	17,000	-
Lower Mississippi	Lower Middle Mississippi	-	4	-	-	-	-	-	-	8,000	-
	Upper Lower Mississippi	-	3	-	2	-	-	-	-	7,000	-
Baton Rouge to Gulf	Baton Rouge to New Orleans	1	2	-	2	-	-	-	-	6,000	500
	New Orleans to Gulf	1	2	-	1	-	-	-	-	5,000	500
	Old and Atchafalaya Rivers	-	2	-	-	-	1	-	-	17,000	-
	Baton Rouge to Morgan City	1	1	-	-	-	-	-	-	1,000	500
Illinois Waterway	Illinois Waterway	1	12	-	-	4	-	2	2	140,000	500
Ohio River	Upper Ohio	2	2	4	-	-	-	-	-	6,000	1,000
	Middle Ohio	1	3	3	-	-	-	-	-	6,000	500
	Lower Ohio-Three	2	-	1	-	1	-	-	-	5,000	1,000
	Lower Ohio-One	-	-	-	1	-	-	-	-	1,000	-
	Monongahela	1	-	-	-	-	-	-	-	-	500
	Green	-	3	-	-	-	-	-	-	3,000	-
	Cumberland	-	2	-	-	-	1	-	-	17,000	-
Tennessee River	Upper Tennessee	2	1	-	-	-	1	-	-	1,000	1,000
	Lower Tennessee	-	1	-	-	1	-	-	-	6,000	-

CANDIDATE SAFETY ACTIONS FOR STRATEGY IV(1)
(Continued)

Region	Segment	New or Enhanced Vessel Traffic Service Centers(2)	Minor Structural Actions: Bridges(3)	Minor Structural Actions: Locks(4)	Minor Structural Actions: Channels(5)	Major Structural Actions: Bridge Removals	Major Structural Actions: Bridge Alterations	Major Structural Actions: Bridge Replacements	Major Structural Actions: Rock Cuts	Construction (Costs ($000s)(6)	Annual Operating Costs ($000s)(6
Gulf Coast West	New Orleans to Calcasieu River	2	13	-	-	-	3	-	-	58,000	1,000
	Calcasieu to Corpus Christi	1	12	2	-	-	-	-	-	10,000	500
	Houston Ship Channel	(7)	-	-	1	-	-	-	-	1,000	-
Gulf Coast East	New Orleans to Mobile Bay	1	5	-	2	-	-	-	-	12,000	500
	Mobile Bay to St. Marks, Fla.	1	-	-	-	-	-	-	-	-	1,000
Mobile River and Tributaries	Black Warrior-Mobile Harbor	-	10	-	3	-	-	-	-	14,000	-
South Atlantic Coast	Florida/Georgia Coast	2	3	-	-	-	-	-	-	6,000	1,500
Middle Atlantic Coast	Chesapeake and Delaware Rivers	2	8	-	-	-	-	-	-	16,000	2,000
	New Jersey-New York Coast	-	2	-	-	-	-	-	-	4,000	-
North Atlantic Coast	North Atlantic Coast	-	5	-	-	-	-	-	-	10,000	-
Great Lakes/St. Lawrence Seaway	Lake Ontario and Seaway	1	-	-	1	-	-	-	-	5,000	500
	Lake Erie	-	16	-	-	-	-	-	-	32,000	-
	Lake Huron	1	5	-	-	-	-	-	-	10,000	1,000
	Lake Michigan	-	8	-	-	-	-	-	-	16,000	-
	Lake Superior	-	5	-	-	-	-	-	-	10,000	-

CANDIDATE SAFETY ACTIONS FOR STRATEGY IV(1)
(Continued)

Region	Segment	New or Enhanced Vessel Traffic Service Centers(2)	Minor Structural Actions			Major Structural Actions				Construction (Costs ($000s)(6)	Annual Operating Costs ($000s)(6)
			Bridges(3)	Locks(4)	Channels(5)	Bridge Removals	Bridge Alterations	Bridge Replacements	Rock Cuts		
Washington/Oregon Coast	Puget Sound	1	5	-	-	1	-	-	-	11,000	1,000
Columbia-Snake W.	Upper Columbia-Snake	-	-	1	-	-	-	-	-	1,000	-
	Lower Columbia-Snake	1	1	-	-	-	-	-	-	2,000	500
California Coast	San Francisco Bay Area	1	2	-	-	-	-	-	-	4,000	500
	Central/South California	1	-	-	-	-	-	-	-	-	1,000
Alaska	Southeast	1	-	-	-	-	-	-	-	-	500
Hawaii	Hawaii	1	-	-	-	-	-	-	-	2,000	-
TOTAL		30	152	12	14	9	8	2	3	543,000	17,500

Notes: (1) Actions taken in regions with 10,000,000 tons or more of growth by 2003.

(2) Dash indicates no change from present level of services.

(3) Includes such actions as installation of fenders, radar transponders, and radar reflectors.

(4) Includes actions at other waterway structures. Actions at locks include installation of mooring cells and/or guidewalls.

(5) Placement of additional aids to navigation.

(6) Costs expressed in 1977 dollars.

(7) Part of VTS for Gulf Intracoastal Waterway.

EXHIBIT IV-4
Page 1 of 2

Actions to Improve
Linehaul Cost

				Costs ($1,000)		
WWS Region	WWS Segment	Nature of Action	Locks Changed or Replaced(1)	Construction Cost(2)	Other Operations and Maintenance (Annual)(2)	Incremental Maintenance Dredge Volume (100 C.Y.)
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois R.	Deepen to 10' from pool 26 through pool 12. Requires replacement of 6 locks.	L&D 15, L&D 16, L&D 20, L&D 21, L&D 24, L&D 25	$329,000	$0	150,000
2. Lower Upper Mississippi	2. Lower Upper Mississippi, Illinois R. to to Missouri R.	(3)		0	0	0
	3. Middle Mississippi Missouri R. to Ohio R.	Deepen to 12'.		282,506	0	150,000
Baton Rouge to Gulf	7. Mississippi R., Baton Rouge to New Orleans	Deepen to 55'.				
	8. Mississippi R. New Orleans to Gulf	Deepen to 55'		310,000	0	600,000
5. Illinois Waterway	9. Illinois Waterway	Deepen to 12' from pool 26 on Mississippi through Lockport Requires replacement of 7 locks.	Lockport Brandon Road Dresden Island Marseilles Starved Rock Peoria LaGrange	174,000	500	50,000
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha R.	Deepen to 12'. Requires replacement of 2 locks.	Emsworth Dashields	200,000	120	0
	12. Middle Ohio, Kanawha R. to Kentucky R.	Deepen to 12'.		10,000	0	0

EXHIBIT IV-4
Page 2 of 2

Actions to Improve Linehaul Cost

NWS Region	NWS Segment	Nature of Action	Locks Changed or Replaced(1)	Costs ($1,000) Construction Cost(2)	Other Operations and Maintenance (Annual)(2)	Incremental Maintenance Dredge Volume (100 C.Y.)
7. Ohio River (Cont'd)	13. Lower Ohio Three, Kentucky R. to Green R.	Deepen to 12'. Requires replacement of 1 lock.	McAlpine	$135,000	$60	0
	14. Lower Ohio Two, Green R to Tennessee R.	Deepen to 12'.		10,000	0	0
	15. Lower Ohio One, Tennessee R to Mouth	Deepen to 12'. Requires replacement of 2 locks.	L&D 52 L&D 53	270,000	0	0
10. Gulf Coast West	29. GIWW West Two, Calcasieu R., to Corpus Christi	Deepen Port of Galveston to 50'.		100,000	0	0
12. Mobile River and Tributaries	35. Black Warrior-Mobile Harbor	Deepen Port of Mobile to 55'.		300,000	0	7,000
		Widen to allow passage of 8 barge tows.		90,000	0	0
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	Deepen Port of Norfolk/Hampton Roads to 55'.		250,000	0	11,500
		Deepen Baltimore to 50'.		215,000	0	3,100

Notes: (1) Based on a preliminary review of existing depths over sills. The actual requirements for lock modification to accommodate greater drafts would be based on detailed engineering studies.

(2) Costs expressed in 1977 dollars.

(3) Already 12'.

Deferred Maintenance Dredging Included in Strategy IV

NWS Region	NWS Segment	Annual Volume(1) (100 C.Y.)	Base Year Unit Cost(2) ($1 C.Y.)
1. Upper Mississippi	1. Upper Mississippi Minneapolis to Illinois Waterway	2,152	$1.003
2. Lower Upper Mississippi	3. Middle Mississippi Missouri R. to Ohio R.	2,500	0.524
4. Baton Rouge to Gulf	8. Mississippi R., New Orleans to Gulf	6,000	0.433
7. Ohio River	21. Cumberland River	6,000	2.029
8. Tennessee River	23. Lower Tennessee, Junction with Tennesse Tombigbee to Mouth	1,950	1.733
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu R.	2,914	0.701
	29. GIWW West Two, Calcasieu R. to Corpus Christi	40,000	0.314
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile	35,390	0.521
	32. GIWW East Two, Mobile to St. Marks, Fla.	32,410	0.751
12. Mobile River and Tributaries	35. Black Warrior-Mobile Harbor	22,300	0.515
13. South Atlantic Coast	39. Florida-Georgia Coast	22,983	0.819
	40. Carolinas Coast	15,050	0.939
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	53,765	2.018
	42. New Jersey-New York Coasts	22,290	2.061

EXHIBIT IV-5
Page 2 of 2

Deferred Maintenance Dredging
Included in Strategy IV

NWS Region	NWS Segment	Annual Volume(1) (100 C.Y.)	Base Year Unit Cost(2) ($1 C.Y.)
16. Great Lakes, St. Lawrence Seaway	45. Lake Ontario and St. Lawrence Seaway	2,000	$1.208
	46. Lake Erie	350	1.375
	48. Lake Michigan	5,200	2.067
	49. Lake Superior	392	2.409
17. Washington-Oregon Coast	50. Puget Sound	2,000	1.250
	53. Oregon-Washington Coast	8,560	0.805
18. Columbia-Snake	52. Lower Columbia-Snake Waterway	2,500	0.378

Notes (1) Source is NWS inventory.
(2) Unit costs are those presented in Appendix A.

EXHIBIT IV-6

Obsolete Locks Replaced Or Modified Under Strategy IV

NWS Region	NWS Segment	River/ Waterway	Lock Name	Nature of Action	Dimensions of New Chamber Width (feet)	Dimensions of New Chamber Length (feet)	First Cost(2) ($1,000)	Increase in Annual O&M Cost(2) ($1,000)
Upper Mississippi	Upper Mississippi	Mississippi R., Minneapolis to mouth of Illinois R.	L&D 1(1)	Replace existing chambers.	110	600	$29,000	$ 0
Ohio River	Monongahela River	Monongahela River	L&D 3	Replace existing 56' x 360' chamber.	110	720	45,000	0
			L&D 4	Replace existing 56' x 360' chamber.	110	720	45,000	0
			L&D 7	Replace existing chamber.	110	720	45,000	0
			L&D 8	Replace existing chamber.	110	720	45,000	0
	Kanawha River	Kanawha River	Winfield	Replace one existing chamber.	110	600	50,000	0
			Marmet	Replace one existing chamber.	110	600	50,000	0
Gulf Coast West	GIWW West One	Gulf Intra-coastal Water-way	Harvey	Replace existing chamber.	110	1,200	150,000	0
Gulf Coast East	GIWW East One	Inner Harbor Navigation Canal	Inner Harbor	Add a second chamber.(3)	110	1,200	70,000	200
Mobile River and Tributaries	Black Warrior-Mobile Harbor	Warrior River	Oliver	Replace existing chamber.	110	600	70,000	100
Columbia-Snake Waterway/ Williamette River	Upper Columbia Snake Waterway	Columbia River	Bonneville	Replace existing chamber.	86	675	85,000	0

Notes: (1) Rehabilitation completed in fiscal year 1981 is expected to extend the life of the existing facility.

(2) Expressed in 1977 dollars.

(3) Simply replacing the existing chamber with a larger chamber would not substantially increase capacity at this site due to the peculiar nature of the traffic. Therefore a new larger chamber is provided to meet the objective of treating obsolescence and the old chamber is retained to continue to serve traffic that can use it effectively.

Minor Ports and Side Channels(1)

NWS Region	NWS Segment	Minor Ports	Side Channels	Deep Draft	Shallow Draft
2. Lower Upper Mississippi	3. Middle Mississippi Missouri R. to Ohio River		Kaskasia River		X
7. Ohio River	12. Upper Ohio, Kanawha R. to Kentucky River.		Big Sandy River		X
9. Arkansas River	24. Arkansas, Verdigris, White and Black Rivers		White River		X
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu River		Barataria Bay		X
			Houma Canal		X
			Freshwater Bayou		X
	29. GIWW West Two, Calcasieu River to Corpus Christi	Sabine River Channel		X	
			Channel to Arkansas Pass, Texas		X
			Sabine-Neches Channel	X	
			GIWW Alternate Route, Galveston Channel		X X
			Colorado River Channel, Bay City, Texas		X
			Channel to Palacios, Texas		X
			Channel to Port Lavaca		X

Minor Ports and Side Channels(1)

NWS Region	NWS Segment	Minor Ports	Side Channels	Deep Draft	Shallow Draft
10. Gulf Coast West	30. GIWW West Three, Corpus Christi to Brownsville	Port Mansfield, Texas			X
		Channel to Port Mansfield			X
		Harlingen, Texas			X
	34. Houston Ship Channel		Light Draft Channel		X
		Anahuac Channel, Texas			X
		Trinity River Channel			X
		Double Bayou, Texas			X
			Cedar Bayou		X
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile	Bayou La Batre		X	
	32. Mobile to St. Marks, Fla.	Perdido Pass Channel		X	
		East Pass Into Choctawatchee Bay		X	
		Apalachicola Bay		X	

Minor Ports and Side Channels(1)

NWS Region	NWS Segment	Minor Ports	Side Channels	Deep Draft	Shallow Draft
13. South Atlantic Coast	39. Florida - Georgia Coast	Fernandina Harbor, Fla.		X	
			Savannah River Below Augusta		X
	40. Carolina Coast	Shipyard River, S.C.		X	
			Cape Fear River, N.C.		X
		Manteo Bay, N.C.		X	
		Oregon Inlet		X	
		Channel to Hatteras Inlet		X	
		Ocracoke Inlet		X	
		Georgetown Harbor		X	
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	Little River		X	
	42. New Jersey - New York Coasts		Fire Island Inlet		X
			Weehauken - Edgewater Channel, New Harbor	X	
		Cold Spring Inlet		X	
16. Great Lakes - St. Lawrence Seaway	45. Lake Ontario and St. Lawrence Seaway	Rochester, NY		X	
	46. Lake Erie	Port Huron, Mich.		X	
	47. Lake Huron	Monroe Harbor		X	

Minor Ports and Side Channels(1)

NWS Region	NWS Segment	Minor Ports	Side Channels	Deep Draft	Shallow Draft
17. Washington - Oregon Coast	53. Oregon - Washington Coast	Yaquina Bay		X	
		Sinslaw River		X	
		Umpqua River		X	
		Roglee River		X	
		Willapa River		X	
18. Columbia - Snake Waterway	52. Lower Columbia - Columbia - Snake Waterway		Willamette River		X
19. California Coast	55. San Francisco Bay	Petaluma River		X	
	56. Central - South California	Morro Bay		X	
		Santa Barbara		X	
			Channel Islands Harbor	X	
			Oceanside	X	

NOTES: 1 Minor Ports and Side Channels with average annual dredge volumes greater than or equal to 100,000 c.y. Ports and channels reported in the published Waterborne Commerce Statistics as having a controlling depth of 15' or less were considered shallow draft for costing purposes in Appendices A and B.

Projected Dredging Unit Cost Growth Rates

NWS Region	NWS Segment	Compound Growth Rate Percent per Annum
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois R.	5.88%
2. Lower Upper Mississippi	2. Lower Upper Mississippi, Illinois R. to Missouri R.	1.15
	3. Middle Mississippi, Missouri R. to Ohio R.	1.15
3. Lower Mississippi	4. Lower Middle Mississippi, Ohio R. to White R.	1.15
	5. Upper Lower Mississippi, White R. to Old R.	1.15
	6. Lower Mississippi, Old River to Baton Rouge	1.15
4. Baton Rouge to Gulf	7. Mississippi R., Baton Rouge to New Orleans	0.73
	8. Mississippi R. New Orleans to Gulf	0.73
	25. Ouachita, Black and Red Rivers	2.23
	26. Old and Atchafalaya Rivers	1.15
	27. GIWW Port Allen Route	3.33

Projected Dredging Unit
Cost Growth Rates

NWS Region	NWS Segment	Compound Growth Rate Percent per Annum
5. Illinois Waterway	9. Illinois Waterway	1.15%
6. Missouri River	10. Missouri River	1.15
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha R.	2.44
	12. Middle Ohio, Kanawha R. to Kentucky R.	1.15
	13. Lower Ohio Three, Kentucky R. to Green R.	1.15
	14. Lower Ohio Two, Green R. to Tennessee R.	1.15
	15. Lower Ohio One, Tennessee R. to Mouth	1.15
	16. Monongahela R.	4.01
	17. Allegheny R.	4.01
	18. Kanawha R.	4.01
	19. Kentucky R.	1.15
	20. Green R.	1.15
	21. Cumberland R.	4.01

Projected Dredging Unit
Cost Growth Rates

NWS Region	NWS Segment	Compound Growth Rate Percent per Annum
8. Tennessee River	22. Upper Tennessee and Clinch Rivers, Head of Navigation to Junction with Tennessee Tombigbee Waterway	0.00%[1]
	23. Lower Tennessee, Junction with Tennessee Tombigbee to Mouth	1.15
9. Arkansas River	24. Arkansas, Verdigris, White and Black Rivers	4.01
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu R.	1.64
	29. GIWW West Two, Calcasieu R., to Corpus Christi	1.64
	30. GIWW West Three, Corpus Christi to Brownsville	1.64
	34. Houston Ship Channel	4.01
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile	0.89
	32. GIWW East Two Mobile to St. Marks, Fla.	2.53
	33. Florida Gulf Coast	1.15

Projected Dredging Unit
Cost Growth Rates

NWS Region	NWS Segment	Compound Growth Rate Percent per Annum
11. Gulf Coast East	38. Apalachicola, Chattahoochee, and Flint Rivers	2.07%
12. Mobile River and Tributaries	35. Black Warrior-Mobile Harbor	4.76
	36. Alabama and Coosa Rivers	1.90
	37. Tennessee-Tombigbee Waterway(1)	1.15
13. South Atlantic Coast	39. Florida-Georgia Coast	2.00
	40. Carolinas Coast	2.82
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	3.68
	42. New Jersey - New York Coast	0.73
15. North Atlantic Coast	44. Upper Atlantic, New York-Connecticut Boundary to St. Croix R., Maine	2.10
16. Great Lakes, St. Lawrence Seaway	43. New York State Waterways	1.15
	45. Lake Ontario and St. Lawrence Seaway	1.15
	46. Lake Erie	2.65%
	47. Lake Huron	3.57

Projected Dredging Unit
Cost Growth Rates

NWS Region	NWS Segment	Compound Growth Rate Percent per Annum
16. Great Lakes, St. Lawrence Seaway	48. Lake Michigan	2.65%
	49. Lake Superior	3.13
17. Washington-Oregon Coast	50. Puget Sound	2.67
	53. Oregon-Washington Coast	0.73
18. Columbia-Snake Waterway	51. Upper Columbia-Snake Waterway	0.00[1]
	52. Lower Columbia-Snake Waterway	0.73
19. California Coast	54. Northern California	0.73
	55. San Francisco Bay	3.96
	56. Central-South California	1.15
20. Alaska	57. Southeast Alaska	1.15
	58. South Central Alaska	1.15
	59. West and North Coasts of Alaska	4.01
21. Hawaii and Pacific Territories	60. Western Pacific	1.15
22. Caribbean	61. Caribbean	1.15

Note: (1) No dredging occurred in this segment during base period.

V - EVALUATION OF STRATEGIES

INTRODUCTION

This section of this report presents the results of the major integration effort, namely the evaluation of the four strategies. Before the evaluation of the strategies of itself is presented, the evaluation of the present navigation system (presented in detail in the report entitled Evaluation of the Present Navigation System) is summarized and the application of the strategies is briefly discussed. The remainder of this section is organized into the following topics:

- Evaluation of the present system.
- Application of strategies.
- National evaluation.
- Industry evaluation.
- Regional evaluation.
- Summary.

EVALUATION OF THE PRESENT SYSTEM

Water transportation needs have been identified in the Evaluation of the Present Navigation System. Water transportation needs have been defined for purposes of NWS as changes in the navigation system that would be required to handle current and projected waterborne commodity flows safely and at a marine linehaul cost consistent with the historical cost relationship among transportation modes.

The evaluation of the present system found that:

1. A small number of locks and dams are constraining under all four scenarious and sensitivity forecasts.

2. The single largest shortfall in lock capacity under peace-time conditions occurs at Locks and Dam 26.

3. Under a defense emergency, the single largest shortfall in lock capacity occurs at the locks on the St. Mary's River between Lakes Superior and Huron.

4. A much larger number of locks are constraining or highly congested under one or more scenarios.

5. The agriculture and coal industries are most directly affected by shortfalls in lock capacity (over two-thirds of the unaccommodated use is from these industries) and increased lock congestion.

6. The steel industry is also adversely affected by shortfalls in lock capacity.

7. The greatest amount of unaccommodated usage is in the four Mississippi River regions (reflecting the "systemwide" effects of a shortfall in capacity at Lock and Dam 26) and the Illinois, Ohio, and Great Lakes/Seaway regions.

8. Due to changes in traffic conditions, 12 of the 22 regions may be expected to have significant safety problems if offsetting actions are not taken.

9. A small number of locks were also found to be obsolete.

APPLICATION OF STRATEGIES

As described in Figure II-A the next step after the evaluation of the capabilities of the present system was the application of the strategies formulated in Section IV to that system. This step is the process of applying the decision rules of each strategy to the selection of actions, as described in Section IV of this report. This process was initially executed in October of 1980 and the preliminary results were presented to the public in November of 1980. At that time the four strategies were applied to the four basic scenarios and evaluated. Subsequent to the November 1980 public meetings, three additional sensitivity analysis forecasts were developed. These are described in detail in the Element K2 Report (Evaluation of the Present Navigation System). Some other changes to the cost data used in the strategies for actions were also made.

All analyses of strategies subsequent to November 1980 have incorporated the application of all four strategies to the four basic scenarios. However, the strategies were not all applied to the three sensitivity forecasts. This decision was based on the conclusion that little additional information would be obtained from such analyses. Since the sensitivity forecasts were all treated as increments to the High Use Scenario, the only issue was the number of additional locks required and the timing of construction. Further, it was found in November 1980 that Strategies I and II could not satisfy all the needs of the High Use Scenario. Therefore, formally evaluating Strategies I and II against the sensitivity forecasts was not executed, since no significant additional information would be developed. Strategies III and IV were applied to the sensitivity forecasts and where those results differ significantly from other results, they are discussed.

NATIONAL EVALUATION

This discussion presents the results of the analysis at the national level:

- Traffic accommodation.
- Linehaul costs.
- Safety.
- Environment.
- Public costs.

The environmental review of actions is discussed in detail in Appendix C as well.

(a) Traffic Accommodation

Table V-1 presents projected use in millions of short tons by scenario and year. Projected use represents waterborne flows developed with regard to macroeconomic and industry assumptions but without regard to lock capacity shortfalls. This table also presents traffic versus projected usage in percent. Traffic represents those

Table V-1

Projected Use Accommodation by the Present System[1]

	1977	1980	1985	1990	1995	2000	2003
Baseline							
Projected Use (Mil. of Tons)	1,915	2,079	2,195	2,238	2,390	2,486	2,586
Percent Accommodated	100	100	99.9	100	99.7	99.0	98.6
High Use							
Projected Use (Mil. of Tons)	1,915	2,094	2,007	2,297	2,467	2,623	2,727
Percent Accommodated	100	100	99.9	100	99.5	98.4	97.8
Low Use							
Projected Use (Mil. of Tons)	1,915	2,063	2,152	2,152	2,241	2,299	2,380
Percent Accommodated	100	100	99.9	100	100	99.6	99.4
Bad Energy,							
Projected Use (Mil. of Tons)	1,915	2,095	2,213	2,278	2,362	2,393	2,514
Percent Accommodated	100	100	99.4	99.4	99.2	98.9	97.7
Defense							
Projected Use (Mil. of Tons)	1,915	2,094	2,027	2,500	2,467	2,623	2,727
Percent Accommodated	100	100	99.9	97.2	99.5	98.4	97.8
High Coal Exports							
Projected Use (Mil. of Tons)	1,915	2,104	2,245	2,356	2,557	2,771	2,890
Percent Accommodated	100	100	99.9	100	99.5	98.0	97.3
Miscellaneous							
Projected Use (Mil. of Tons)	1,941	2,120	2,238	2,336	2,514	2,680	2,789
Percent Accommodated	100	100	99.0	98.8	97.9	96.7	96.2

NOTE: [1]Projected waterborne flows have been developed without regard to considerations of lock capacity.

waterborne flows that can be accommodated by the present waterways system.[1]

As can be seen, approximately one to two percent of total projected use cannot be accommodated due to lock capacity shortfalls. Since domestic use is affected far more directly by these shortfalls, the percent of unaccommodated use ranges from one to three in 2003.

It should be emphasized that the projected use and percent accommodated figures displayed in Table V-1 is for all commerce on the total system. It includes shallow draft waterways, the Great Lakes, and the coastal ports. It also includes both domestic and foreign traffic. While a few percentage points shortfall may not seem significant, one percent of all projected use in the year 2003 varies from 24 million tons for the Low Use Scenario to almost 29 million tons for the High Coal Export forecast. The shortfall in 1990 under the Defense Scenario is 70 million tons not accommodated. The largest total shortfall under any peacetime forecast is 77 million tons under the High Coal Export forecast in the year 2003.

A number of constraining and congested locks have been identified from the present system evaluation. Table V-2 lists the major structural actions taken to increase lock capacity by each strategy for the Baseline Scenario. Table V-2 also lists those locks found to be constraining or congested for the baseline scenario.

As can be seen, Strategy I takes the smallest number of actions during the study period. Due to its budget limitation and its priorities for spending, Strategy I adds only a second chamber at Locks and Dam 26. The five constraining locks of the Welland Canal section of the St. Lawrence Seaway are assumed to be expanded by the Canadian government, the owner and operator of the Welland Canal.

---

[1]The present system includes all navigable and/or maintained rivers, canals, ports, and waterways as of December 1978. (See Exhibit I-1 of the Evaluation of the Present Navigation System.) In addition, it includes among other ongoing projects the Tennessee-Tombigbee Waterway, the Red River (Shreveport to Mississippi) and the single 1200' x 110' chamber at Locks and Dam 26 on the Mississippi.

Table V-2

Lock Actions Taken by Strategy
(Baseline Scenario)

Region	Lock Name	Strategy I	Strategy II	Strategy III	Strategy IV
Primary Constraining Locks[1]					
2	Lock & Dam 26	X	X	X	X
7	Gallipolis		X	X	X
12	Demopolis			X	X
16	Welland Canal[2]	X	X	X	X
Secondary Constraining Locks[3]					
1	Lock & Dam 22		X	X	X
5	LaGrange		X	X	X[4]
5	Peoria		X	X	X[4]
5	Marseilles		X	X	X[4]
Congested Locks[5]					
1	Locks 16,20,21,24 and 25				X[6]
1	Locks 17, 18 and 19				
2	Lock & Dam 27				
5	Starved Rock				X[4]
5	Lockport				X[4]
7	Uniontown				X
7	Newburgh				7
7	McAlpine				X[4]
7	Dashields				X[4]
7	Emsworth				X[4]
8	Kentucky				
10	Harvey[8]				X[9]
10	Algiers				
11	Inner Harbor[8]				X[9]
12	Warrior				
12	Oliver[8]			X	X[9]
16	St. Mary's River				X
18	Bonneville[8]				X[9]
Other Locks					
1	Lock 1[8]				X[9]
1	Lock 15				10
5	Dresden Island				X[4]
5	Brandon Road				X[4]
7	L&D 52				X[4]
7	L&D 53				X[4]
7	Monongahela Locks 3, 4, 7 and 8[8]				X[9]
7	Winfield and Marmet Locks on the Kanawha[8]				X[9]
	TOTAL	6	11	13	40

NOTES:

[1] Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

[2] Locks 1, 2, 3, 7 and 8 are constraints and capacity is added to each.

[3] Constraining only if additional capacity is provided at primary (controlling) locks.

[4] Action taken to accommodate 12' channel.

[5] Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[6] Locks 16, 20, 21, 24 and 25 are replaced to accommodate 10' channel.

[7] Delays are reduced by effect of deepening on lock capacity.

[8] Obsolete lock.

[9] Action taken to address lock obsolescence.

[10] Action taken to accommodate 10' channel.

It should be noted that NWS formulated actions on a lock-by-lock basis for the Welland Canal. The option currently under consideration by the Canadian authorities is to construct a totally new canal parallel to the existing facility. No other actions to expand lock capacity are taken, including actions for the remaining six constraining locks.

By way of contrast, Strategy II is subject to the same budget limitations. Yet, capacity is added at all United States owned and operated locks that are constraining, with the single exception of Demopolis. In the case of Demopolis, lock capacity is not added by 2003 but would be shortly thereafter under Strategy II's decision rules. Strategy II adds capacity wherever one million tons or more of grain and energy use cannot be accommodated.

While Strategy II does a much better job of addressing shortfalls in lock capacity, it does not construct any additional capacity for congested locks.

Under Strategy III lock capacity is expanded at all commercially important locks when chamber utilization exceeds 95%. Accordingly, actions are taken by 2003 at all constraining locks and one congested lock by this Strategy under the Baseline Scenario.

Strategy IV takes actions at all commercially important locks when chamber utilization exceeds 85%. In addition, Strategy IV deepens channels in the Mississippi, Ohio and Illinois Rivers. As part of these channel deepening actions, some existing chambers are replaced by larger chambers with greater depths over sill. Finally, Strategy IV replaces obsolete locks.

The total lock actions under the four strategies range from six to 40 under the Baseline Scenario. Exhibits V-1, V-2, and V-3 present this same information for the High Use, Low Use and Bad Energy scenarios, respectively. As can be seen, the range in lock actions under these three scenarios is quite comparable to the range of actions under the Baseline scenario. A maximum of 44 distinct lock actions would be taken by Strategy IV under the High Use Scenario. Strategy IV would take the same actions under the Miscellaneous Sensitivity and two additional actions

Table V-3

Traffic Versus Projected Use in 2003
(Percent)

Scenario/ Sensitivity	Present System	Strategy I	II	III	IV
Baseline					
Domestic	97.8	99.0	98.4	100.0	100.0
Foreign	99.6	100.0	100.0	100.0	100.0
High Use					
Domestic	97.0	98.0	97.8	100.0	100.0
Foreign	98.6	100.0	100.0	100.0	100.0
Low Use					
Domestic	98.8	99.7	98.5	100.0	100.0
Foreign	100.0	100.0	100.0	100.0	100.0
Bad Energy					
Domestic	97.2	98.1	98.2	100.0	100.0
Foreign	98.3	100.0	100.0	100.0	100.0
High Coal					
Domestic	96.1	NC	NC	100.0	100.0
Foreign	98.8	NC	NC	100.0	100.0
Miscellaneous					
Domestic	94.4	NC	NC	100.0	100.0
Foreign	98.6	NC	NC	100.0	100.0

NOTES: NC denotes not calculated.

under the High Coal Export Sensitivity at Bankhead Lock on the Black Warrior River and at Lock and Dam 1 on the Green River.

Table V-3 presents traffic versus projected use by scenario and strategy in 2003. The ratios of traffic to projected use are shown separately for domestic and foreign commerce.

As can be seen, Strategy I does not handle all domestic usage in 2003. Its single discretionary lock action, namely the addition of a second chamber at Locks and Dam 26, increases traffic substantially. This action combined

with the increase in capacity of the Welland Canal locks cuts the number of tons not handled by over 50% relative to the present system.

Strategy II does a slightly poorer job of accommodating projected use in 2003 than does Strategy I. This finding appears to be surprising in view of this strategy's emphasis on adding capacity at constraining locks. However, Strategy II takes federal funds away from minor ports, side channels, and Class "C" inland segments that are costly to maintain and operate and spends federal funds on Class "A" and Class "B" segments. Accordingly, in 2003, Strategy II does a poorer job of accommodating projected use due to its withdrawal of federal funds from:

1. Kentucky River in 1995.

2. Apalachicola, Chattahoochee, and Flint Rivers in 1995.

3. Alabama and Coosa Rivers in 2000.

4. Ouachita, Black, and Red Rivers in 2000.

5. Arkansas River in 2003.[2]

The analysis makes the extreme assumption that projected use for these waterways disappears with the withdrawal of federal support.

Although Strategy II does a poorer job than Strategy I of accommodating projected use in 2003, it may well do a better job of accommodating projected use beyond 2003.[3]

Table V-4 compares the annual tonnage increase in projected use for selected locks and Class "C" inland segments. The numbers shown are in millions of tons and represent the average increase in projected use from 2000 to

---

[2]This segment classification changes under the sensitivity analysis in Section VI.

[3]The NWS limited the analysis to 2003, but investments in waterway structures are long-term strategic investments in assets with economic lives of 50 years or more.

Table V-4

Annual Growth in Projected Use from 2000 to 2003
(Millions of Tons)

	Baseline	High Use	Low Use	Bad Energy	High Exports	Misc. Sensitivities
Constraining Locks						
Gallipolis	1.3	1.2	1.0	1.0	1.2	1.3
Lock and Dam 26	2.9	2.8	2.3	3.7	3.5	3.2
LaGrange	0.9	1.0	0.8	2.8	1.0	1.0
Demopolis	1.4	1.7	1.3	1.5	2.3	1.7
Class "C" Inland Segments						
Kentucky	0.0	0.0	0.0	0.0	0.0	0.0
Apalachicola-Chattahoochee-Flint	0.0	0.0	0.0	0.0	0.0	0.0
Ouachita-Black-Red	0.0	0.0	0.0	0.0	0.0	0.0
Alabama-Coosa	0.0	0.0	0.0	0.0	0.0	0.0
Arkansas	0.1	0.1	0.0	0.3	0.2	1.1

2003. The locks included in this table are constraining locks, where additional capacity is added as part of Strategy II under one or more scenarios. The Class "C" inland segments are those segments for which federal supports is withdrawn as part of Strategy II under one or more scenarios.

As can be seen by Table V-4, the annual tonnage increase use at potentially constraining locks is far greater than the annual tonnage increase in use for Class "C" inland segments. Strategy II reallocates funds from class "C" segments to those segments with major waterborne flows. In general the incremental tonnage at these key locks exceeds the increments on the "C" segments. Significantly, the Arkansas River has the largest increment of the "C" segments, and under one forecast the increment on the Arkansas exceeds the increment at LaGrange Lock on the Illinois. The point of this discussion and Table V-4 is that Strategy II trades off tons in low growth areas, at least for most of the forecasts displayed. Under the "Miscellaneous" forecast, the Arkansas segment is growing as rapidly as traffic on the Illinois Waterway at LaGrange Lock and Dam.

Since Strategies III and IV add capacity before it is exceeded by projected use, domestic and foreign commerce are completely accommodated.

(b) Linehaul Costs

The discussion of linehaul costs is divided into the inland waterways; Great Lakes; and coastal ports.

1. Inland Waterways. Table V-5 presents aggregate national costs in mills per ton-mile for all domestic inland movements. These costs include only those for linehaul operations. No attempt is made to estimate the total costs of water-based logistics systems, which might include costs for truck or rail feeder movements, handling, storage, and fleeting. Costs are expressed in 1977 dollars. Costs are shown by scenario and strategy.

As can be seen, linehaul costs are slightly lower under Strategy I relative to the present system. This

Table V-5

Private Linehaul Costs for Domestic Inland Waterways Traffic in 2003
(Mills per Ton-Mile[1])

Scenario/ Sensitivity	Present System	Strategy I	II	III	IV
Baseline	10.8	10.5	10.3	10.4	9.3
High Use	10.7	10.5	10.3	10.2	9.2
Low Use	10.9	10.6	10.5	10.5	9.5
Bad Energy	10.7	10.5	10.2	10.2	9.2
High Coal Export	10.7	NC	NC	10.1	9.0
Miscellaneous	10.9	NC	NC	10.3	9.2

NOTES: [1] 1977 dollars.

NC denotes not calculated.

reduction in linehaul costs is due to the addition of a second chamber at Locks and Dam 26.[4]

Linehaul costs under Strategy II are in turn slightly lower than Strategy I. These findings are not surprising in view of this strategy's efforts to reallocate funds to those segments with major waterborne flows.

For two of the four scenarios, there is no reduction in average linehaul costs under Strategy III vis-a-vis Strategy II. For the remaining scenarios, the differences between linehaul costs under Strategies III and II are small. The apparent rise in linehaul cost between Strategy II and Strategy III is the result of more tons being accommodated on waterways with high linehaul costs.

---

[4]Not all the reduction in linehaul costs may be attributable to reductions in tow delay at Locks and Dam 26. It is, at least, possible that the additional traffic handled under Strategy I moves, on average, at a lower ton-mile cost.

With regard to Strategy IV, linehaul costs show a sizable decline from Strategy III. In each instance, domestic linehaul costs decline one mill (or approximately 10%) per ton-mile. The reduction in ton-mile costs are due both to the channel deepening (the productivity improvement of larger ladings is only partially offset by the use of towboats with more horsepower) and the construction of larger and/or additional chambers at many more locations throughout the waterways.[5]

Table V-6 illustrates the potential reductions in private linehaul costs from adopting programs similar to Strategies I-IV.[6] These reductions are expressed in millions of 1977 dollars and have been calculated by multiplying projected use in ton-miles for the baseline scenario in 2003 by the differences in the linehaul costs for 2003 between the present system and the system as modified by the strategies.

The construction of a second chamber results in a substantial reduction in private linehaul costs. The estimated reduction in costs for 2003 is $57 million in 1977 dollars. Additional reductions in aggregate private linehaul costs are obtained under Strategy II and again in Strategy III.

The reductions in private costs from adopting programs and policies similar to Strategy IV are, however, far greater than for other strategies. Costs are reduced by $558 million in 2003. As can be seen, regions such as the Gulf Coast West and Baton Rouge to Gulf, which already have major waterways with channel depths of 12 feet, also benefit from the "systemwide" channel deepening of Strategy IV. Increasing channel depths in other parts of the system permits shippers to load barges in these two regions at depths in line with existing 12-foot channel dimensions. These reductions in linehaul costs are discussed further in the regional evaluation of strategies.

---

[5]See Appendix D for a discussion of how the deepening actions were addressed in the analysis.

[6]These reductions in linehaul costs are not equivalent to benefits as calculated by the Corps of Engineers for economic evaluation of proposed projects. No attempt has been made as part of NWS to replicate project-level analysis.

Table V-6

Reduction in Private Linehaul Costs[1] for Domestic Inland Traffic in 2003 Strategy (Millions of 1977 Dollars for Baseline Scenario)

Region	Strategy I	II	III	IV
Upper Mississippi	2	11	11	29
Lower Upper Mississippi	57	57	57	94
Lower Mississippi	0	0	13	142
Baton Rouge to Gulf	4	11	(4)	42
Illinois Waterway	0	14	13	40
Missouri River	0	(1)	(1)	(1)
Ohio River	(9)	0	0	115
Tennessee River	0	1	4	4
Arkansas River	0	NC	0	0
Gulf Coast West	0	0	25	55
Gulf Coast East	0	1	1	4
Mobile River and Tributaries	0	13	15	34
TOTAL	54	107	134	558

NOTES: ( ) denotes negative number.
NC denotes not calculated.

2. Great Lakes/Seaway. The average linehaul costs of domestic Great Lakes/Seaway shipments are presented in Table V-7 by scenario and strategy. These costs are computed in 1977 dollars for 2003 and are expressed in mills per ton-mile.

Little reduction in linehaul costs are realized for the Great Lakes under any strategy under any scenario. The maximum gain is one tenth of a mill. This occurs primarily in those instances where capacity is added at the St. Mary's River locks.

No additional lock actions are taken under Strategy III, except in the case of the High Use scenario. For this scenario, capacity is added at the St. Mary's River locks and some reduction in aggregate linehaul costs is achieved. The further reduction in linehaul costs for Strategy IV is also obtained from adding capacity at the St. Mary's River locks.

Table V-7

Private Linehaul Costs for Domestic Great Lakes/Seaway Traffic in 2003 (Mills per Ton-Mile[1])

Scenario/ Sensitivity	Present System	Strategy I	II	III	IV
Baseline	3.0	3.0	3.0	3.0	2.9
High Use	3.0	3.0	3.0	2.9	2.9
Low Use	3.0	2.9	2.9	2.9	2.9
Bad Energy	2.9	2.9	2.9	2.9	2.9
High Coal Export	3.0	NC	NC	2.9	2.9
Miscellaneous	3.0	NC	NC	2.9	2.9

NOTES: [1]1977 dollars.
NC denotes not calculated.

Table V-8 presents the estimated reduction in linehaul costs for Great Lakes traffic in 2003 from adopting policies and programs similar to Strategies I-IV. As can be seen, these reductions for the Baseline Scenario occur only when capacity is added at the locks on the St. Mary's River. This is done only by Strategy IV under the Baseline Scenario.

Table V-8

Reduction in Private Linehaul Costs[1] for Domestic Great Lakes/ Seaway Traffic in 2003 by Strategy

Region	Strategy I	II	III	IV
Great Lakes/Seaway	0	0	0	13

NOTE: [1]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present waterways system and the modified system under each of the four strategies.

This $40 million dollar savings would be realized earlier under a strategy designed to provide capacity at the St. Marys River Locks in advance of a defense emergency. Comparable or higher savings would be realized

during the hypothesized defense emergency, releasing resources for other uses.

3. Coastal Ports. Linehaul costs were not computed for foreign commerce. However, the linehaul costs of shipments of such bulk commodities as petroleum, grain, and coal will be substantially reduced by deepening of coastal ports that handle large volumes of this type of commerce. Strategy IV includes channel deepening at the coastal ports of Hampton Roads, Baltimore, New Orleans/ Baton Rouge, Mobile, and Galveston. Studies have been completed by the Corps of Engineers for the purpose of determining the economic benefits of such projects.

(c) Safety

Table V-9 presents a list of the number of safety actions taken by region for Strategies I-IV. The regions included in this table are those which were identified in the Evaluation of the Present Waterways System as having potential safety problems in the future due to changing traffic conditions. These changing conditions include traffic growth, increases in tow or vessel delays at locks, increasing tow sizes, and high levels of hazardous cargoes.

As can be seen, no additional safety actions above and beyond current programs and policies can be taken under Strategy I. Strategy I has only sufficient funding after the completion of the present system in 1990 to add a second chamber at Locks and Dam 26 and operate and maintain the rest of the Waterway.[7]

In sharp contrast to Strategy I, Strategy II "reallocates" expenditures of funds so that the overwhelming majority of safety actions of Strategies III and IV, which have no budget limits, can be taken. The safety actio are clearly targeted to those regions where increases in the potential for safety problems can be expected.

---

[7]Strictly speaking, Strategy I runs out of funds to operate and maintain the entire system after 2000.

Table V-9

Number of Safety Actions Taken by Strategy
From 1985 to 2003
(Baseline Scenario)

Region	Strategy I	II	III	IV
Upper Mississippi	0	11	11	29
Lower Upper Mississippi	0	9	9	9
Baton Rouge to Gulf	0	11	14	14
Illinois	0	20	20	21
Ohio	0	27	27	27
Tennessee	0	4	4	5
Gulf Coast West	0	34	34	34
Gulf Coast East	0	9	9	9
Tombigbee-Warrior	0	13	13	13
Great Lakes-Seaway	0	31	31	37
Washington-Oregon	0	7	7	7
Alaska	0	1	1	1
Other	0	12	12	12
TOTAL	0	188	191	200

Actions taken to enhance safety under the peacetime scenarios would also be required in some areas for the defense scenario. Strategies which do not anticipate defense related safety problems (e.g., increased movements of hazardous cargo) will not adequately provide for safety in a wartime environment.

(d) Environment

Appendix C describes the environmental impacts of the NWS actions in detail. It is difficult to generalize about environmental impacts of actions due to the need to qualify such statements for local conditions in the immediate and surrounding area in which actions are taken.

However, environmental impacts on aquatic, terrestrial and wetland habitats as well as water quality are most likely for these actions:

- Maintenance dredging.
- Channel deepening.
- Port deepening.

Strategy IV has the potential for the most effects on the environment associated with dredging. By taking actions to reduce federal support of dredging activity for Class "C" inland segments, minor ports, and side channels, Strategy II may have fewer impacts on the environment.

Since Strategy I provides no funding for safety actions, it may have greater impacts on the environment due to a less safe environment for navigation.

(e) Public Costs

Some of the public costs of operating, maintaining and improving the waterways for the entire period of the study (1977 to 2003) are presented in Table V-10. As is true of all public costs in this section of the report, they include estimated Corps of Engineers' expenditures for maintenance dredging, other operations and maintenance, rehabilitation, and construction. In addition, the costs include the construction and operating expenses of additional safety actions above and beyond those actions of existing programs and practices. No costs are included for the United States Coast Guard or the St. Lawrence Seaway. All costs are expressed in billions of 1977 dollars for each scenario - strategy combination.

For the Baseline scenario, these public costs range from $16.4 to 22.5 billion. Public costs do not differ significantly by scenario. However, they do differ sharply by strategy. Thus, public policy decisions about what, when, and how to provide for the operation, maintenance, and improvement of the waterways should have greater impact upon the size of public expenditures than actual waterway traffic growth over the next 20 years.

While Table V-10 provides estimates of the aggregate expenditures under each strategy, it tells little about the allocation of resources during the study period under alternative strategies. Figure V-A presents a graph of annual expenditures for the completion, operation, maintenance, and rehabilitation of the present system as defined by NWS. For each of the seven time periods, annual waterway expenditures are plotted in millions of 1977 dollars. The budget limit of $585 million used in Strategies I and II is also shown in this figure as a dashed line.

Table V-10

Public Expenditures for Waterways by Scenario from 1977 to 2003[1] (Billions of 1977 Dollars)

Scenario	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Baseline	16.3	16.4	16.4	17.6	22.5
High Use	16.3	16.4	16.3	18.2	24.5
Low Use	16.3	16.4	16.4	17.5	22.3
Bad Energy	16.3	16.4	16.4	17.8	23.8
High Coal Exports	16.3	NC	NC	18.5	24.7
Miscellaneous	16.3	NC	NC	18.7	24.6

NOTE: [1]Includes estimated Corps of Engineers' expenditures for navigation. Excludes existing levels of U.S. Coast Guard and Seaway expenditures. The costs shown in Table V-10 do include incremental costs for construction, operation and maintenance of additional actions to enhance safety, most of which are the responsibility of the U.S. Coast Guard.

NC denotes not calculated.

As can be seen by Figure V-A, annual public expenditures exceed the budget limit after 2000. So a "business-as-usual" strategy such as Strategy I will simply not provide for adequate funding of the entire waterways after 2000 and it will certainly not have adequate funds for expanding lock capacity or enhancing existing safety programs.

Figure V-B presents a graph of these same annual public expenditures by type of expense. As can be seen, the construction costs to complete the present system are substantial. While costs for other operations and maintenance are projected to remain flat in constant dollars, channel maintenance and rehabilitation costs escalate sharply for reasons discussed in Section IV.

Figure V-C presents annual public expenditures for all four strategies from 1977 to 2003. As can be seen, Strategies I-III have reasonably comparable costs. However, the costs for Strategy IV to improve the system are markedly higher.

Figure V-A

Annual Public Costs of the Present System from 1977 to 2003
(Millions of 1977 Dollars)

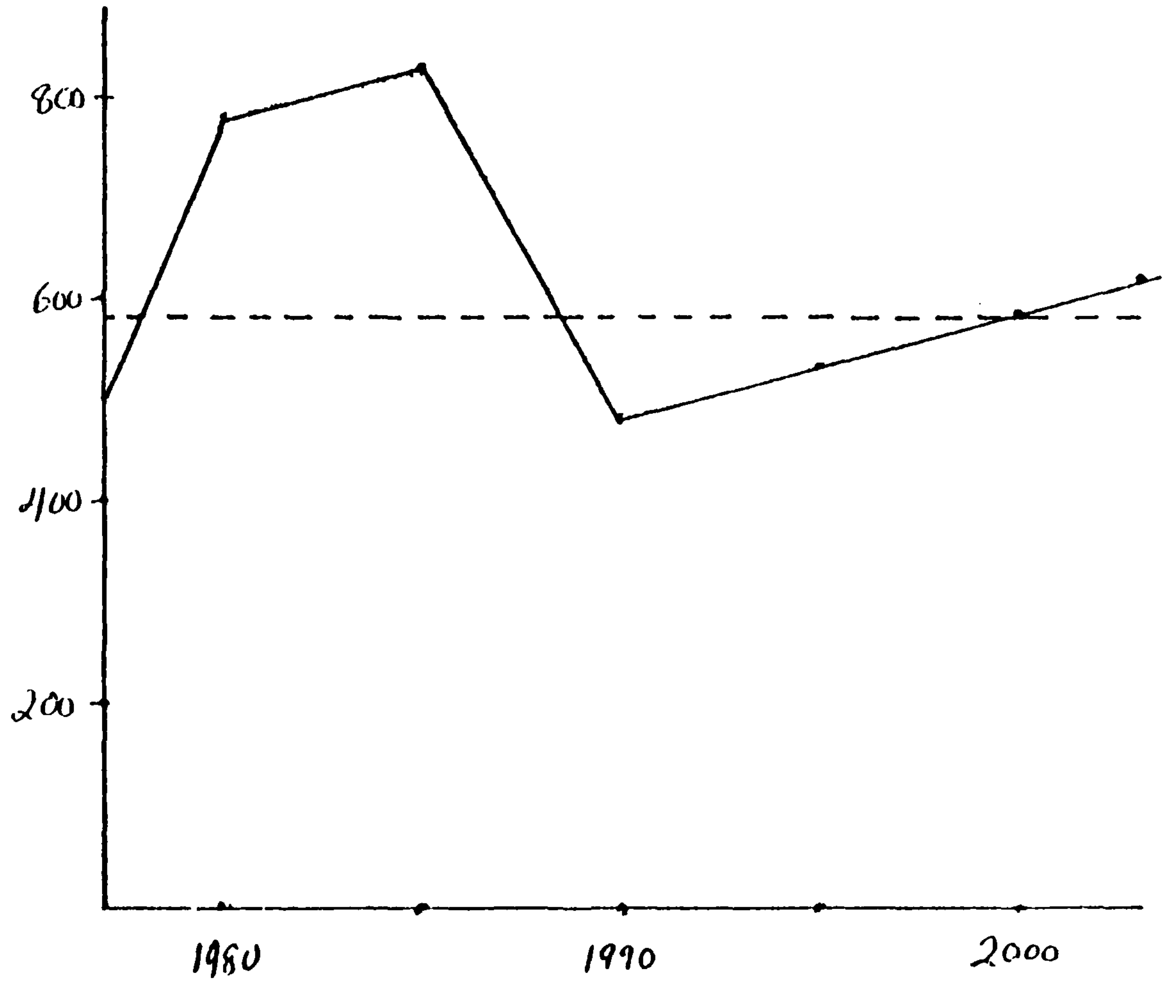


Figure V-B

Annual Public Costs of the Present System by Expense Type from 1977 to 2003
(Millions of 1977 Dollars)

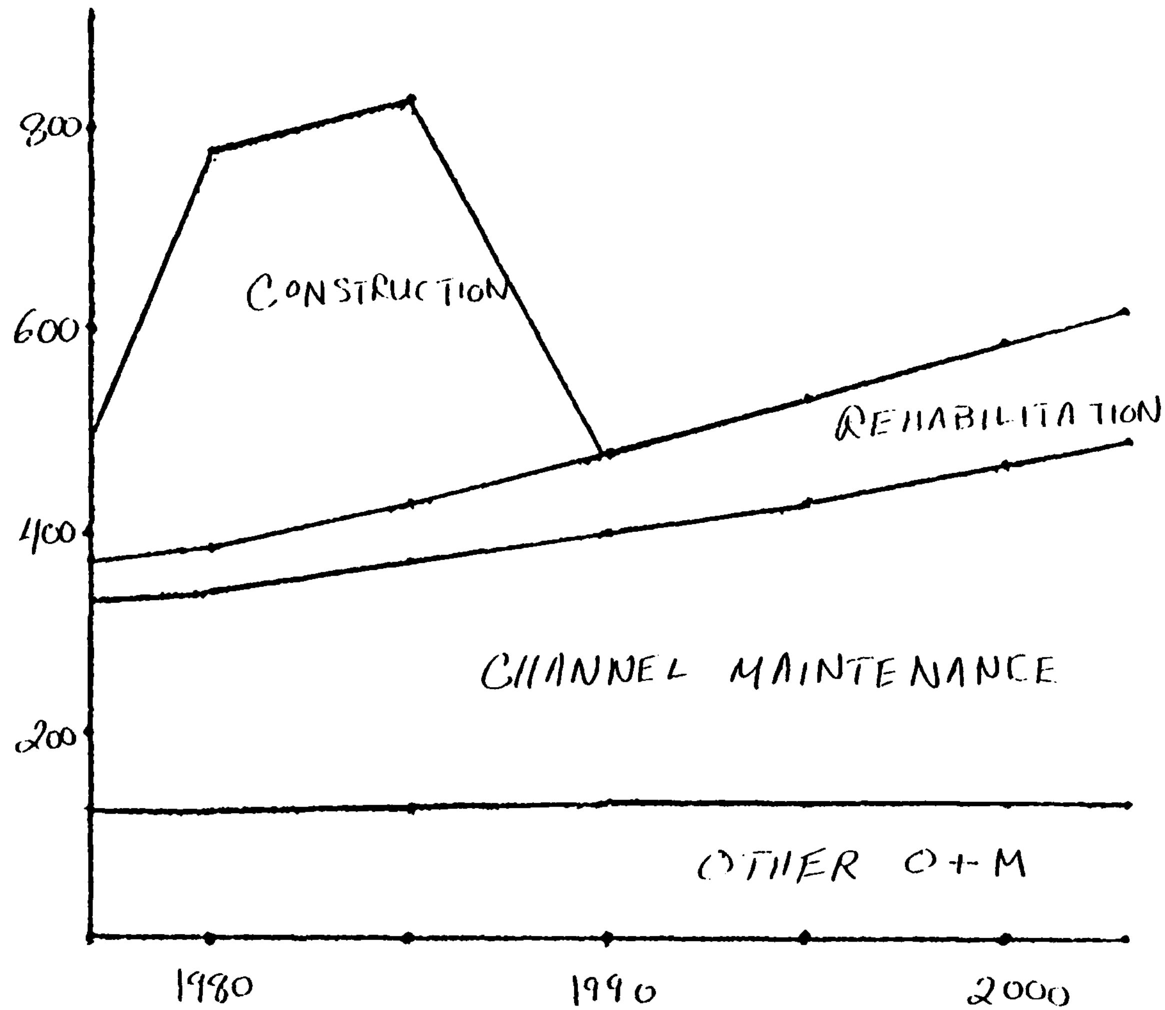


Figure V-C

Annual Public Costs by Strategy from 1977 to 2003
(Millions of 1977 Dollars - Baseline Scenario)

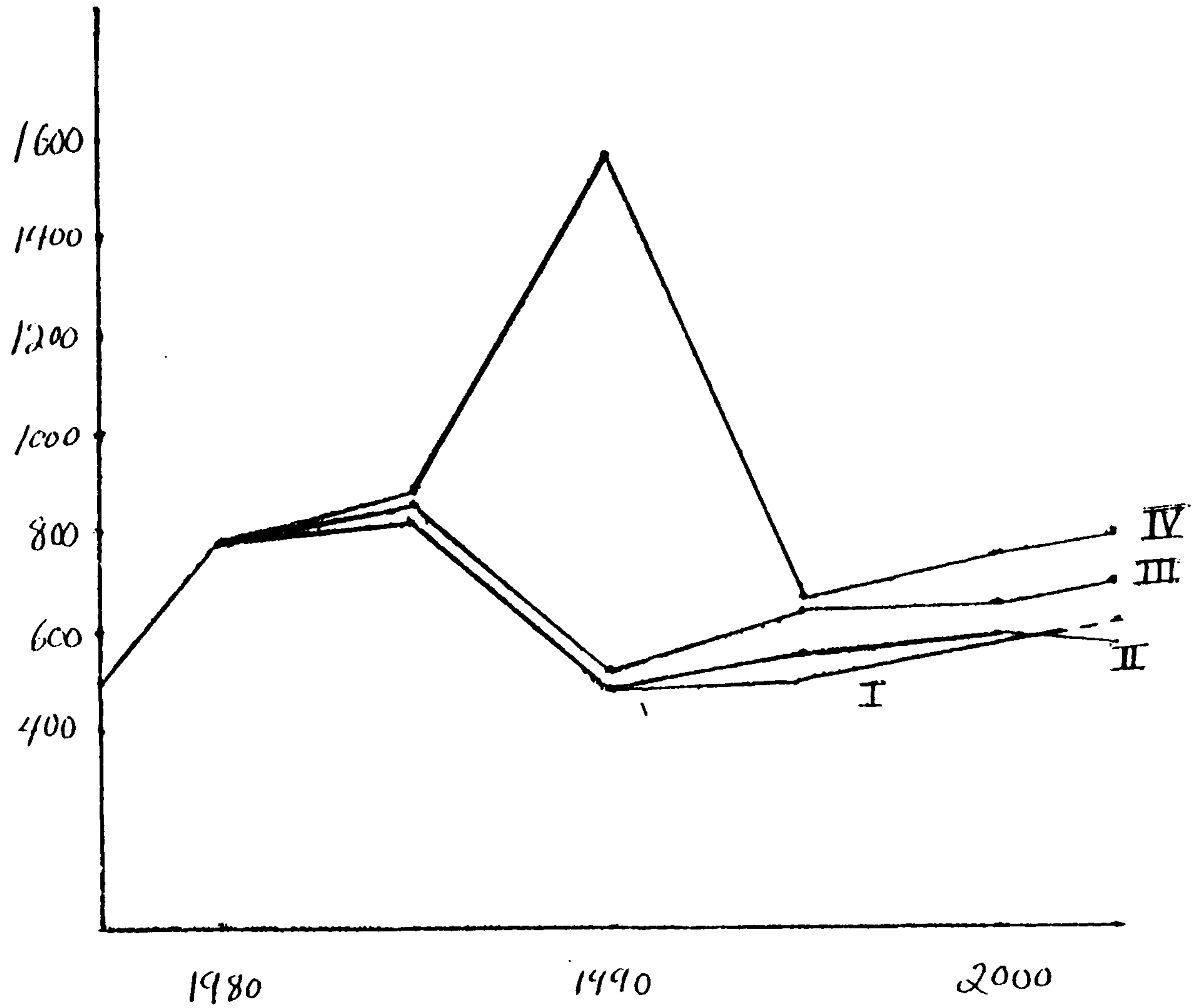


Table V-11 presents public costs for 1977 to 2003 by type of waterways expense. As can be seen, maintenance dredging and construction are the items accounting for the significant differences in total expenditures across the four strategies.

Table V-11

Public Expenditures for Waterways by Type of Expense from 1977 to 2003[1] (Billions of 1977 Dollars)

Expense	Present System	Strategy I	II	III	IV
Maintenance Dredging	7.4	7.4	6.8	7.4	9.0
Other Operations and Maintenance	3.6	3.6	3.5	3.8	3.9
Rehabilitation	2.1	2.1	2.0	2.1	1.9
Construction	3.2	3.3	4.1	4.3	7.7
TOTAL	16.3	16.4	16.4	17.6	22.5

NOTE: [1]See footnote 1 to Table V-10. Expenditures are for Baseline scenario.

Since all strategies include a large component of costs for operations and maintenance, and Strategy IV incorporates certain fixed construction actions, the only variation in costs across scenarios arises from the number of locks built. For example, the difference in cumulative expenditures of 2.2 billion between the Baseline and High Coal Exports shown for Strategy IV in Table V-10 is solely for additional locks, all in the inland shallow draft system. The same pattern persists for other strategy scenario combinations, although the spread in costs is lower.

Finally, Table V-12 presents public costs by type of waterway. All costs are for the 1977-2003 period.

Over 50% of the public expenditures for present system operations and completion are for the inland waterways. These relatively high costs reflect in large part the completion of the Tennessee-Tombigbee Waterway, the Red River project, Locks and Dam 26, and other projects under construction.

Table V-12

Public Expenditures for Waterways
by Type of Waterway from 1977 to 2003[1]
(Billions of 1977 Dollars)

Waterway	Present System	Strategy I	II	III	IV
Inland	9.6	9.7	10.2	10.8	13.2
Great Lakes/ Seaway	1.0	1.0	0.9	1.1	1.3
Coasts	5.7	5.7	5.3	5.7	8.0
TOTAL	16.3	16.4	16.4	17.6	22.5

NOTE: [1]See footnote 1 to Table V-10. Expenditures are for Baseline scenario. Costs are approximate since segment definitions for NWS do not fall "nearly" into inland, lakes, and coastal categories. The costs for rehabilitation and safety actions for some coastal segments which include both deep draft and shallow draft facilities have not been allocated.

Over 50% of the public expenditures for Strategies I-III are for the inland waterways as well.

Expenditures are increased sharply, however, for both inland and coastal waterways under Strategy IV. Inland waterway costs are increased as a result of the channel deepening and lock replacement actions. Coastal waterway costs are increased as a result of port deepening actions and actions to undertake deferred maintenance dredging. As shown in Figure V-C, about 37% of the construction expenditure in 1990 by Strategy IV is for coastal deep draft port deepening.

The distributions of public expenditures displayed in Tables V-11 and V-12 show some variance across the scenarios and sensitivity forecasts. The major differences occur in construction costs depending on the number of locks built as can be seen in Table V-2 and the exhibits to this section. Since all the locks which create costs in these tables are on the inland system except the St. Mary River Locks, most of the differences across the other forecasts also occur in the inland system.

Public costs for the Great Lakes and Seaway show little change across the four strategies, but it should be remembered that the costs for operating, maintaining, and improving the Welland Canal section and the St. Lawrence River section of the Seaway are not included in these totals.

According to information provided by the St. Lawrence Seaway Development Corporation through the Corps of Engineers the costs for expanding the Welland Canal are estimated at two billion dollars in 1981 dollars. These costs, plus the Operations and Maintenance Costs are not displayed in any of the tables, exhibits, or figures in this report.

(f) Fuel Tax Revenues

The previous paragraphs have described the magnitudes of expenditures of public funds generated by the different strategies. The federal government will also receive revenues in future years from the shallow draft inland system under existing law (PL 95-502). The revenue estimates for the existing fuel tax for the entire nation are summarized in Table V-13 below.

Table V-13

Annual Fuel Tax Revenues in 2003
($ million)

	Strategy			
Scenario/Sensitivity	I	II	III	IV
Baseline	82.2	76.8	80.1	77.6
High Use	85.7	82.3	83.6	81.1
Low Use	73.3	68.3	71.2	69.4
Bad Energy	85.7	80.7	83.2	80.8
High Coal Exports	NC	NC	87.7	85.1
Miscellaneous	NC	NC	93.5	87.9

NC denotes not calculated.

The different levels of revenues across the scenarios reflect the different levels of total activity in the system which is subject to the tax. The revenues of Strategy

I are greater than Strategy II and III because of the delays at locks. Strategy II is the lowest of the first three strategies because of the loss of traffic on Class "C" Segments, which require more energy per ton-mile than other inland segments. Strategy IV generates the lowest revenues primarily because of the favorable effect of channel deepening on fuel efficiency. The additional reductions in lock delays made possible by Strategy IV also depress revenues.

INDUSTRY EVALUATION

This evaluation focuses on two key measures of concern to shippers:

- Traffic accommodated by the system.
- Private linehaul costs.

(a) Traffic Accommodation

Table V-14 presents domestic waterway traffic as a percent of total projected use by industry. The percent of domestic traffic handled is presented for both the present system and the modified system for each strategy.

Table V-14

Percent of Domestic Traffic Handled in 2003[1]
(Baseline Scenario)

Industry	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Agriculture	89.4%	96.6%	97.7%	100%	100%
Fertilizer/ Chemicals	96.2	98.0	96.5	100	100
Steel	99.0	99.5	97.9	100	100
Coal	98.0	98.6	98.7	100	100
Petroleum	99.4	99.7	99.4	100	100
Forest Products	99.9	99.9	97.2	100	100
Other	99.4	99.6	98.0	100	100
	97.8%	98.9%	98.4%	100%	100%

NOTE: [1]All strategies accommodate 100% of foreign traffic.

As can be seen, there is a marked improvement in traffic accommodated for the agriculture industry under all four strategies. However, the failure to expand capacity up-river of Locks and Dam 26 under Strategy I still limits traffic growth. Strategy II does not accommodate all projected use due principally to the withdrawal of federal support for the Arkansas River.

Since the Bad Energy Scenario projects somewhat higher levels of agricultural exports, the agriculture industry is somewhat more severely affected by lock capacity shortfalls which Strategies I and II do not correct. Strategy I accommodates only 92% of domestic agricultural projected use in 2003 and Strategy II handles 98% in 2003 under the Bad Energy Scenario.

There is also an improvement in traffic accommodated for the coal industry under Strategies III and IV. The failure of Strategy I to expand lock capacity at Gallipolis on the Upper Ohio limits coal traffic growth. The withdrawal of federal support for the Arkansas under Strategy II results in the disappearance of over five million tons of projected coal use.

Only Strategies III and IV were evaluated under the High Coal Export Forecast and these strategies relieve all constraints. Therefore all projected use for coal would be accommodated by these strategies for this forecast.

All other waterway user industries show a slight improvement in traffic accommodated under Strategies I and II under the Baseline Scenario except for small reductions in traffic handled under Strategy II for the forest products and "other" industries due to withdrawal of support for various Class C Segments. The pattern of performance is similar for these industries in other strategy scenario combinations.

The industry most affected under the Defense Scenario is the Steel Industry. Only Strategies III and IV were evaluated for the Defense forecast and these would accommodate all tonnage. While Strategies I and II were not evaluated under this forecast it is important to point out

that neither of these strategies would add capacity at the key Defense constraint, the locks on the St. Mary's River between Lakes Huron and Superior. Strategy II would fund such an investment if Defense requirements were incorporated into its priorities. The important point about all the strategies is that strategies designed to meet peacetime needs will not meet defense needs at all or will meet them late in the study period. Thus, in the event of a defense requirement earlier in the study period, no strategy will meet the lock capacity requirements for this industry.

(b) Linehaul Costs

In addition to traffic accommodation, waterway users are concerned with the rate of increase in the costs of their water-based logistics systems. Traditionally, the federal government has affected the linehaul portion of these costs by its programs and policies for waterway operations and maintenance. The landside portion of these costs, while a very important component of total marine-logistics-system costs, has only been indirectly affected by the federal government through regulations of facility construction and operation, railroads, trucking companies, and so on. This discussion focuses strictly on the linehaul costs of domestic marine traffic.

Table V-15 presents private linehaul costs for domestic waterways traffic by industry. Costs are presented in mills per ton-mile using 1977 constant dollars.

As can be seen, average linehaul costs show modest declines for the agriculture and "other" industries under Strategies I-III. By way of contrast, little or no declines in average linehaul costs are achieved for the other industries under Strategies I-III.

However, the story is sharply different for Strategy IV. All industries with the exception of the forest products industry show significant reductions in linehaul costs under Strategy IV. These reductions are greater than one mill per ton-mile for the agriculture, fertilizer/chemicals, and other industries. Declines of 0.7 mills per ton-mile are also achieved on average for the steel and coal industries. Thus, the systemwide impacts

Table V-15

Private Linehaul Costs for Domestic
Waterways Traffic by Industry in 2003[1]
(Baseline Scenario - Mills per Ton-Mile[2])

Industry	Present System	Strategy I	II	III	IV
Agriculture	6.8	6.5	6.3	6.4	5.6
Fertilizer/ Chemicals	10.6	10.5	10.2	10.4	9.3
Steel	4.5	4.5	4.3	4.5	4.1
Coal	7.4	7.4	7.3	7.3	6.6
Petroleum	6.2	6.2	6.1	6.2	5.7
Forest Products	6.0	6.0	5.8	6.0	5.9
Other	14.4	14.4	14.1	14.3	13.3
National	7.9	7.8	7.7	7.8	7.1

NOTES: [1]Average linehaul costs for domestic inland, Great Lakes/Seaway, and coastal traffic.

[2]1977 dollars.

of the Strategy IV's improvement actions benefit the majority of the waterway user industries. This pattern prevails across all scenario/strategy combinations which were evaluated.

Under the High Coal Export forecast, quite a few additional actions are taken to add lock capacity by Strategies III and IV. As a result, average domestic linehaul costs for the coal industry under this forecast in the year 2003 were 7.1 mills per ton-mile and 6.5 for Strategies III and IV respectively. When Strategies III and IV are applied to the Defense scenario, some lock capacity expansions would be accomplished earlier. This in turn would reduce linehaul costs during the Defense emergency for some industries, particularly the Steel industry. Linehaul costs in 1990 under Strategy III would be 3.3 mills per ton mile and under Strategy IV would be 3.1 mills, compared to 3.8 mills under the present systems.

REGIONAL EVALUATION

This evaluation of the four NWS strategies focuses on these measures:

1. Projected usage not accommodated by the waterways system due to lock capacity constraints.

2. Average linehaul costs for domestic shipments by water.

3. Average delay at locks.

4. Average lock utilization.

5. Public expenditures (Corps of Engineers' expenditures and incremental costs for new safety actions).

6. Revenues collected from P.L. 95-502 fuel taxes.

In addition, actions taken under each strategy are discussed. Although actions are presented in the same table with measures, they should not be confused with measures.

The findings with regard to each of the 22 regions are discussed briefly below. The discussion focuses on the baseline scenario, because it is necessary to have a common basis for evaluating the four NWS strategies. However, where findings are changed under one or more of the other three scenarios, then the discussion includes measures for other scenarios.

(a) Upper Mississippi

The evaluation of the present system found that:

1. Problems with Locks and Dam 26 as well as with Lock and Dam 22 severely limit traffic growth beyond 1995[8].

---

[8]Locks and Dam 26 is located in the Lower Upper Mississippi region, but a high percentage of Upper Mississippi traffic must pass this facility.

2. Average delays increase substantially due to increased lock congestion.

3. Increases in delay, traffic, and average tow sizes can be expected to pose new safety problems in the future.

Table V-16 shows the evaluation measures for the present waterways system and all four strategies under the baseline scenario in the year 2003. All measures are reported for the single year 2003, with the single exception of public expenditures. Public expenditures are reported for 1977-2003. All dollar figures are in constant 1977 dollars.

As can be seen, there is a substantial improvement in traffic handled under all strategies. The single "discretionary" lock action of Strategy I, namely the construction of a second 1,200' chamber at Locks and Dam 26, greatly increases the amount of southbound traffic that can be originated and northbound traffic that can be terminated on the Upper Mississippi. The lack of funds for expansion of Lock and Dam 22 under Strategy I results in some diversion of traffic. Less than two percent of projected usage cannot be accommodated.

Strategy II "reallocates" funds from side channels in the Upper Mississippi (see Appendix A) and other waterways for the construction of Lock and Dam 22. As a result, less than one percent of projected use is not accommodated in 2003. Seven additional locks (six for the channel deepening action and one for the replacement of obsolete locks) are replaced under Strategy IV.

The replacement of Lock and Dam 22 results in a lowering of average linehaul costs under Strategies II and III by 0.5 mills per ton-mile. Average linehaul costs under Strategy I are not significantly different from those of the present system, since no actions within the region were taken to improve linehaul costs. Linehaul costs under Strategy IV are 1.3 mills per ton-mile below those of the present system and, as a result of taking Strategy IV actions, the annual reduction in linehaul costs to shippers is estimated to be $29 million in 2003. These

Table V-16

Regional Evaluation Report
for Upper Mississippi in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use (%)	83	98	99	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	10.8	10.7	10.3	10.3	9.5
Reduction in Linehaul Costs ($ Million)[2]	N/A	2	11	11	29
Average Lock Delays (Hours)	21.7	18.4	12.4	12.3	6.3
Average Lock Utilization (%)	64	64	63	63	51
Locks Built	0	0	1	1	8
Safety Actions Taken	0	0	10	10	11
Public Expenditures 1977-2003 ($ Million)[3]	1,110	1,110	1,132	1,238	1,664
Fuel Tax Revenues in 2003 ($ Million)[4]	N/A	6.7	6.0	6.0	5.4

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

Strategy IV actions include the replacement of Locks 15, 16, 20, 21, 24 and 25 (as part of the 10-foot channel deepening action) with larger chambers having greater depth over sill.

Lock delays remain very high under Strategy I due to the severe congestion at Lock and Dam 22. Average lock utilization, however, shows little difference from the present system except under Strategy IV.

No safety actions can be taken under Strategy I due to the budget limitations. The Upper Mississippi is one of 12 regions where there is potential for increases in new safety problems. Thus, this failure to take offsetting actions is a serious shortcoming of Strategy I.

All candidate actions to improve safety in Exhibit IV-2 for the Upper Mississippi are taken in Strategies II and III. Fenders and radar reflectors are installed at eight bridges and one lock. Navigation aids are improved at one channel location. Safety actions are also taken under Strategy IV as indicated in Exhibit IV-3. The sites of these actions are listed in Exhibit IV-3 of the Element K2 Report (Evaluation of the Present Navigation System). In addition to some minor structural actions, two bridges are removed, two bridges are altered to increase horizontal clearance, and one rock cut is made.

Public expenditures for Strategy II increase above those of Strategy I. Public expenditures increase modestly under Strategy III, but increase sharply under Strategy IV. Construction costs for the channel deepening project; replacements of the obsolete chamber at Lock and Dam 1 and the congested chamber at Lock and Dam 22; and the safety actions total nearly $600 million under Strategy IV. And annual maintenance dredging costs increase $2 to $4 million after the completion of the 10-foot deepening project in 1990. These higher construction and dredging costs are offset only partially by lower lock rehabilitation costs.

Fuel tax revenues range from $5 to $7 million in 2003. Fuel tax revenues are highest under Strategy I due to the increased congestion and longer waiting times at Lock and Dam 22.

The evaluation results for other scenarios and sensitivity forecasts do not vary greatly from the Baseline for

this region. Since there is only one constraining lock in this region under any scenario (Lock and Dam 22) the variations across scenarios and strategies depend largely on whether or not capacity is added at this site. Under the Low Use scenario capacity is not added at Lock and Dam 22 under Strategy II for example, yet linehaul costs are lower than under the Baseline because total delays are still lower.

(b) Lower Upper Mississippi

In the absence of offsetting actions, the Lower Upper Mississippi region is expected to have major problems with capacity shortfalls, increasing traffic, and increasing lock delays. Locks and Dam 26 (even with new 1,200-foot chamber to be completed as part of the present system in 1990) restrict traffic to 85% of projected use in 2003. And the Lower Upper Mississippi is one of twelve regions with potential for increased safety problems in the future.

Table V-17 presents strategy evaluation measures for 2003.

As can be seen, all projected use is accommodated under Strategies III and IV and less than one percent of projected use is not accommodated under Strategy II. But up-river lock capacity shortfalls on the Illinois and Upper Mississippi Rivers limit traffic to less than 95% of projected use under Strategy I. The major improvement in Strategy I relative to the present system is, of course, attributable to the construction of a second chamber at Locks and Dam 26.

By 2003, average linehaul costs are reduced by as much as two mills per ton-mile under Strategies I-III and by another 1.3 mills under Strategy IV as a result of the 12-foot channel deepening project. The large amount of projected usage and the substantial reduction in average linehaul costs result in major reductions in private operating costs. The reductioon in annual private operating costs for 2003 alone ranges from $57 to $94 million.

Table V-17

Regional Evaluation Report
for Lower Upper Mississippi in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use (%)	85	95	99	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	11.5	9.5	9.5	9.5	8.2
Reduction in Linehaul Costs ($ Million)[2]	N/A	57	57	57	94
Average Lock Delays (Hours per Tow)	3.9	1.4	1.3	1.3	0.8
Average Lock Utilization (%)	98	72	72	72	59
Locks Built	1	2	2	2	2
Safety Actions Taken	0	0	9	9	9
Public Expenditures 1977-2003 ($ Million)[3]		905	918	924	1,414
Fuel Tax Revenues ($ Million)[4]	N/A	6.2	6.2	6.2	6.1

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

Lock delays and lock utilization are lower under all strategies. However, average utilization levels under Strategies I-III in 2003 are still some of the higest utilization levels of any waterway region. The further reduction in delays and utilization under Strategy IV is attributable solely to the channel-deepening project not the construction of additional locks. The Lower Upper Mississippi along with the Illinois and Ohio Rivers are deepened to 12 feet under Strategy IV.

No safety actions are taken under Strategy I even though the Lower Upper Mississippi is one of 12 regions with potential safety problems. Minor structural actions at eight bridges and one channel location are taken under Strategies II-IV.

Public expenditures for the strategies are higher than those for the present system. The higher costs of Strategy I are due to the construction of a second 1,200 foot chamber at Lock and Dam 26, the only "discretionary" action that can be funded under Strategy I.

The public costs of Strategy II are greater than those of Strategy I. Under the reallocation scheme of Strategy II, the Lower Upper Mississippi region benefits by obtaining additional resources for safety actions. These safety actions are "financed" in part by the withdrawal of federal support for other waterways, ports, and side channels. And in 1995, it is necessary to withdraw federal support of the Kaskaskia River project, a project that has been classified as a side channel for NWS.

No such withdrawal of federal support is necessary under Strategies III and IV. The large increase in costs for Strategy IV are due to increased dredging during 1985 to 1990 for the deepening of the channel from the mouth of the Missouri to the mouth of the Ohio (first costs exceed $300 million in 1977 dollars) and annual increases in dredging (nearly $10 million in 1977 dollars) for maintenance of the 12-foot channel and resumption of previously deferred dredging.

Fuel tax revenues are about $6 million in 2003 for all strategies under the Baseline Scenario.

Since the actions are the same for each for all scenarios, the only variation in evaluation measures across scenarios occurs in the items that are affected by projected use. Under the Bad Energy Scenario and the Low Use Scenario for example, delays at locks are lower even though the same actions are taken.

(c) Lower Mississippi

There are no locks in this region and this region was not identified as one of the twelve regions with potential safety problems. However, the region is greatly affected by up-river constraints and there is substantial projected traffic growth during the period. As much as nine percent of the projected usage of this region is not accommodated by the present system due to up-river lock constraints in 2003.

Locks and Dam 26 is the single most important lock restricting the amount of traffic reaching this region. Since Strategy I's only "discretionary" action is the construction of a second chamber at Locks and Dam 26, traffic increases sharply under Strategy I (see Table V-18 on the following page for this region's strategy evaluation measures). Lock constraints on the Illinois, and secondarily on the Upper Mississippi (Lock and Dam 22) and Ohio Rivers still limit the amount of traffic that reaches this region to 97% of projected use in 2003. Problems begin to develop as early as 2000 under Strategy I.

Traffic is almost completely accommodated under Strategy II through 2000, since capacity at up-river locks with significant diversions (over 1 million tons) of projected grain and coal use is expanded.

However, Strategy II "reallocates" funds from side channels, minor ports, and Class "C" inland segments to faster-growing, lower-public-cost Class "A" and "B" segments. With the withdrawal of federal support for the Arkansas waterway in 2003 under Strategy II and, to a lesser degree, the withdrawal of federal support for the Ouachita, Black, and Red Rivers in 2000, two percent of the Lower Mississippi's projected use disappears. Accordingly, while Strategy II addresses potentially constraining locks (for which traffic grows faster in the long run than for the Arkansas waterway), Strategy II has the short-term effect of reducing traffic below the levels of Strategy I. Of course, the analysis makes the extreme

Table V-18

Regional Evaluation Report
for Lower Mississippi in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use (%)	91	97	95	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	6.6	6.6	6.6	6.5	5.5
Reduction in Linehaul Costs ($ Million)[2]	N/A	0	0	13	142
Safety Actions Taken	0	0	9	9	9
Public Expenditures 1977-2003 ($ Million)[3]	500	500	498	517	517
Fuel Tax Revenues ($ Million)[4]	N/A	21.2	21.0	22.4	22.4

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

assumption that, without federal support, Arkansas traffic will decline. The close proximity of the Lower Mississippi to the Arkansas makes this an unusual, but not unique event. As might be expected, there is some degree of traffic interaction between the Arkansas, on the one hand, and the Baton Rouge to Gulf region, on the other hand.

Minor structural safety actions are taken at seven bridges and two channel locations under Strategies II-IV. The costs of these actions are modest.

Fuel tax revenues in 2003 range from $21 to $22 million.

(d) Baton Rouge to Gulf

The evaluation of the present system found that:

1. Up-river locks restrict traffic to 93% of this region's projected domestic usage in 2003.

2. Sharp increases in traffic, a relatively high percentage of hazardous cargoes and a mix of shallow and deep-draft traffic all combined to make this one of twelve regions where potential safety problems could develop over and above existing problems.

Table V-19 presents the strategy evaluation measures. As in the case of the Lower Mississippi, the present system's shortfall in capacity at Locks and Dam 26 has a dramatic impact on the percentage of projected usage that can be accommodated in 2003. Fully seven percent of projected domestic usage does not reach the region due to up-river lock constraints. Strategy I's "discretionary" action of the construction of a second 1,200' chamber at Locks and Dam 26 does result in an increase in traffic. However, the failure of Strategy I to address other lock constraints on the Illinois and Upper Mississippi Rivers leads to some traffic diversion. By 2003, as much as two percent of the region's projected use disappears due to up-river lock constraints.

As in the case of the Lower Mississippi, Strategy II does a poor job of accommodating this region's projected use. With the withdrawal of federal support for the Ouachita, Black, and Red Rivers in 2000 and the Arkansas in 2003, three percent of the region's projected use disappear.

Table V-19

Regional Evaluation Report
for Baton Rouge to Gulf 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	94	98	95	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	8.0	7.9	7.7	8.1	6.9
Reduction in Linehaul Costs ($ Million)[2]	N/A	4	11	(4)[3]	42
Safety Actions Taken	0	0	11	14	14
Public Expenditures 1977-2003 ($ Million)[4]	2,669	2,669	2,582	2,717	3,576
Fuel Tax Revenues ($ Million)[5]	N/A	1.1	0.5	0.7	0.7
Average Lock Utilization (%)		15	29	15	14

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Parentheses denote a negative number. This is a result of a different traffic mix accommodated by Strategy III.

[4]Cumulative public expenditures for 1977-2003.

[5]Receipts collected under P.L. 95-502 in 2003 for Old and Atchafalaya Rivers; Ouachita, Black and Red Rivers (except under Strategy II); and GIWW Bypass from Baton Rouge to Morgan City, LA.

Domestic linehaul costs show little significant change from those of the present system except under Strategy IV, when the channel deepening of the Illinois Waterway and the Ohio, and Mississippi Rivers permit a significant increase in average barge ladings. The reduction in private operating costs in 2003 is estimated to be $42 million.

Safety actions are taken under Strategies II, III, and IV. Three actions involving vessel traffic services and eight other minor structural actions at bridges and channel locations are taken under Strategy II (see Exhibit IV-2), but no actions are taken in the Old and Atchafalaya Rivers under Strategy II due to its classification as a Class "C" inland segment (see Table IV-3).

This region is composed of widely different waterways and other actions taken under Strategies II and IV highlight these differences.

On the one hand, it is necessary to withdraw federal support of the Ouachita, Black, and Red Rivers in 2000 under Strategy II. This segment is a Class "C" inland segment and is expected to have one of the highest public costs for operations and maintenance (even after ignoring the large construction costs of the project) per ton-mile of projected usage. Although the Red River project was considered to be a "given" for completion, federal support is withdrawn 10 years following its completion under Strategy II in order to finance expenditures for Class "A" and "B" segments.

In addition, federal support is withdrawn under Strategy II for side channels off the Mississippi River from New Orleans south.

Thus, this region benefits from Strategy II insofar as additional traffic is accommodated in the long run and safety actions are taken during the study period, but is loses federal support for several of its navigation projects.

On the other hand, Strategy IV provides for increased maintenance dredging (beginning in 1990) of 600,000 cubic yards of "deferred channel maintenance" and even more importantly the deepening of the Mississippi River from the Gulf to the Port of Baton Rouge. The first costs for the deepening project exceed $350 million in 1977 dollars and the annual increase for maintenance of this deeper channel represents a substantial increase in annual dredging costs.

No attempt was made to estimate the savings in line-haul costs from such a port deepening project as part of NWS, but the Interim Report of the Interagency Coal Export Task Force published in January 1981, notes that similar port deepening on the East Coast would reduce the delivered costs of United States coal to Europe by as much as $6.00 per ton. Detailed Corps project studies of the Baton Rouge and New Orleans port deepening proposals show substantial transportation savings from the exports of grain and grain products as well as the imports of petroleum, petroleum products, and ores.

Public expenditures for this region are substantial under all four strategies. Nearly $2 billion is spent on the Ouachita, Black, and Red Rivers, with the overwhelming proportion of these funds being spent on the completion of the Red River from Shreveport to the Mississippi River.

Public expenditures for the Mississippi River south of Baton Rouge more than double under Strategy IV relative to the present system.

Fuel tax revenues are collected only in the three shallow-draft segments and, as a result, few funds are collected. In 2003, the revenues range from $500,000 to $700,000.

Since there are few locks in this region, the strategies vary little across scenarios. Also, the withdrawal of support from "C" segments in the Region under Strategy II was done under all scenarios. It should be noted that NWS included the Inner Harbor Lock and Mississippi River Gulf Outlet in a different region (Gulf Coast East). Actions at the Inner Harbor Lock are discussed under that region.

(e) Illinois
Waterway

The evaluation of the present system found that:

1. Fourteen percent of projected domestic usage and could not be accommodated due to lock capacity shortfalls. The shortfall in foreign traffic is due to constraints on the Welland Canal on the Great Lakes.

2. Increasing traffic, lock delays, and average tow sizes could increase the potential for new safety problems in the future.

Table V-20 presents the strategy evaluation measures. The completion of the second 1,200' chamber at Locks and Dam 26 under Strategy I does increase traffic. However, shortfalls at LaGrange and secondarily Peoria and Marseilles limit domestic traffic to 93% of projected use in 2003.

In sharp contrast, Strategy II takes resources away from other waterways, ports, and side channels and "reallocates" these resources to constructing additional lock capacity and improving safety on the Illinois Waterway. Strategy II has sufficient funding to expand lock capacity at all three constraining locks on the Illinois Waterway (LaGrange in 1995 and Peoria and Marseilles in 2000). No additional locks are built under the more "generous" funding rules of Strategy III.

As part of Strategy IV's 12-foot deepening project on the Illinois, all seven locks (including Lockport, Brandon Road, Dresden Island, and Starved Rock) are replaced with larger chambers having greater depth over sills.

Average linehaul costs show no change under Strategy I. Thus, once again, Strategy I performs poorly for this region.

The construction of additional lock capacity under the other strategies does result in a significant reduction in average linehaul costs. Annual reductions in aggregate

Table V-20

Regional Evaluation Report
for Illinois Waterway 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	86	93	100	100	100
Foreign (%)[2]	95	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	9.4	9.4	8.4	8.5	6.6
Reduction in Linehaul Costs ($ Million)[3]	N/A	0	14	13	35
Average Lock Delays (Hours per Tow)	8.4	7.8	3.2	3.2	0.6
Average Lock Utilization (%)	85	85	77	77	41
Locks Built	0	0	3	3	7
Safety Actions Taken	0	0	20	20	21
Public Expenditures 1977-2003 ($ Million)[4]	265	265	599	600	1,263
Fuel Tax Revenues ($ Million)[5]	N/A	3.5	2.9	2.9	2.5

NOTES: [1]All dollars are 1977 dollars.

[2]Deep draft traffic at the Port of Chicago.

[3]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[4]Cumulative public expenditures for 1977-2003.

[5]Receipts collected under P.L. 95-502 in 2003.

operating costs for the private sector range from $13 to $30 million in 2003.

Lock delays are significantly lower under Strategies II, III, and IV. However, average lock utilization under Strategies II and III remain very high - some of the highest lock utilization levels of any of the regions.

Strategy I has no funds to take safety actions. Minor structural actions are taken at 17 bridges and 2 channel locations under Strategies II and III. Four bridges are removed, two are replaced, and two rock cuts are made under Strategy IV in addition to the construction of fenders and reflectors at 12 bridges.

The range in public expenditures from the present system to Strategy IV is substantial. As noted earlier, additional construction funds (approximately $334 million) are "reallocated" under Strategy II to the Illinois River. However, a major jump in resources (construction funds approach $1 billion during the period) takes place under Strategy IV. Some of these greater construction costs are offset by reduced rehabilitation costs.

Fuel tax revenues in 2003 range from $3 to almost $4 million. Once again, revenues are higher when tows are forced to wait in line at highly congested locks under Strategy I.

One significant difference between scenarios in this region is the performance of Marseilles Lock under the Defense Scenario. The application of Strategies III and IV to the Defense Scenario would result in capacity being added earlier at this site. Another possible difference, not analyzed in detail, would come under the application of Strategy II to the High Coal Exports Forecast. While Strategy II, as actually analyzed, generally provides substantial funding for lock capacity to accommodate agricultural exports, the High Coal Export Forecast would probably generate different decisions and allocate funds elsewhere.

(f) Missouri River

There are no locks in this region to constrain traffic growth and, as was shown in the evaluation of the present system, the traffic on the Missouri River interacts only

to a small degree with those waterways having constraining locks. Some potential safety problems may arise from the modest increase in average tow size, but traffic is projected to grow slowly.

Table V-21 presents the strategy evaluation measures. Under three of the four strategies, traffic is completely accommodated. And it is nearly accommodated under Strategy I.

Table V-21

Regional Evaluation Report for Missouri River 2003[1] (Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use (%)	98	99	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	22.6	22.7	22.8	22.8	22.8
Reduction in Linehaul Costs ($ Million)		0	-1	-1	-1
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	240	240	236	240	240
Fuel Tax Revenues ($ Million)[3]	N/A	1.7	1.7	1.7	1.7

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

[3]Receipts collected under P.L. 95-502 in 2003.

Linehaul costs show no significant differences. No safety actions are taken under any of the four strategies. Side channels were identified for possible withdrawal of federal support under Strategy II (see Appendix A). However, the Missouri River was classified as a Class "B" inland segment (see Table IV-3) and federal support for the entire waterway continues through 2003 under all four NWS strategies.

Public expenditures show no change across the strategic options except for the reduction in federal support under Strategy II in 1995. Public costs are $240 million in 1977 dollars from 1977 to 2003. Fuel tax revenues in 2003 are estimated to be $2 million.

(g) Ohio River

The evaluation of the present system found that:

1. Ohio River waterborne traffic growth is substantial despite constraining locks in the region (Gallipolis and Uniontown) and some traffic interaction with other regions with constraining locks (principally Lock and Dam 26 in the Lower Upper Mississippi).

2. Lock constraints limit traffic to 97% of projected usage in 2003.

3. Increased traffic, sharply higher average tow sizes, and increasing lock delays suggest that the Ohio River has the potential for increased safety problems in the future if offsetting actions are not taken.

Table IV-22 shows the strategy evaluation measures under the Baseline Scenario for the Ohio River. No actions are taken under Strategy I to add capacity to Gallipolis (the constraining lock in the Ohio River region under the Baseline scenario). Accordingly, Ohio River traffic falls short of projected usage by over 7 million tons in 2003.

Projected usage is more nearly accommodated under Strategy II, since this strategy reallocates resources from the Kentucky River, the Big Sandy (a side channel project in the Ohio River region), and other waterways in other regions for the construction of an additional chamber at Gallipolis in 1995. The Kentucky River carried 465,116 tons of commerce in 1977 and the Big Sandy carried 1,282,480 tons. Another side channel in this region, the Muskingum River, carried 5,600 tons in 1977.

Under the more "generous" decision rules of Strategy III, an additional chamber is also constructed at Uniontown by 2003.

Table V-22

Regional Evaluation Report for Ohio River 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use (%)	97	97	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	10.2	10.3	10.2	10.2	8.9
Reduction in Linehaul Costs ($ Million)[2]	N/A	9	0	0	115
Average Lock Delays (Hours per Tow)	4.9	5.6	4.3	4.3	2.2
Average Lock Utilization (%)	41	41	41	40	27
Locks Built	0	0	1	2	13
Safety Actions Taken	0	0	27	27	27
Public Expenditures 1977-2003 ($ Million)[3]	1,108	1,108	1,364	1,438	1,980
Fuel Tax Revenues ($ Million)[4]	N/A	21.0	20.7	20.8	19.7

NOTES: [1]All dollars are 1977 dollars. Data includes tributaries. See Exhibit I-1 for definition of Ohio Region.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

The diversity of the waterways in the Ohio River region is underscored by the lock capacity actions in Strategy IV and the expenditure reduction actions in Strategy II.

On the one hand, under Strategy IV, the main stem of the Ohio River is deepened to 12 feet by additional dredging and the construction of additional chambers with greater depth over sills at Locks and Dams 52 and 53 and McAlpine on the Lower Ohio and Dashields and Emsworth on the Upper Ohio. In addition, obsolete locks are replaced with larger chambers at Locks 3, 4, 7, and 8 on the Monongahela and Winfield and Marmet on the Kanawha. These locks replacements are above and beyond those for Gallipolis and Uniontown.

On the other hand, under Strategy II, it is necessary to withdraw federal support of the "high" cost Kentucky River, a Class "C" segment, and the Big Sandy Project, one of several side channels for which federal support is withdrawn by 1995.

The major improvement in average linehaul costs come from the 12-foot channel deepening action and actions to replace obsolete locks of Strategy IV. Average linehaul costs fall over one mill per ton-mile for an average annual reduction in private operating costs of $115 million in 2003.

Average lock delay and utilization show no reduction under Strategy I. Reductions are, however, achieved in average lock delays under the other three strategies and in average lock utilization under Strategy IV. In fact, the utilization of lock capacity under Strategy IV is very low for a major waterway region - less than 30% in 2003.

Safety actions are not taken under Strategy I, despite the fact that the Ohio River region was found to have the potential for increased safety problems.

Twelve actions at bridges, eight actions at highly congested locks, one action at a channel location, and six enhanced vessel traffic service actions are taken under Strategies II and III (see Exhibit IV-2). A bridge removal and a bridge alteration are made under Strategy IV in lieu of two minor structural actions under the other strategies.

Public expenditures show substantial variation across all four strategies. For the Ohio tributaries, the deferred maintenance dredging of the Cumberland River along with the replacement of obsolete locks on the Monongahela and Kanawha Rivers account for the principal differences between the public costs of the present system and Strategy IV. Public costs of the safety actions are responsible for the increase in Strategy III costs for the Ohio tributaries.

The 12-foot channel deepening action as well as the major structural actions to improve safety increase the construction costs of Strategy IV by over $500 million during the study period. However, as noted earlier, the estimated reduction in private operating costs are substantial and these higher public construction costs are partially offset by lower costs for rehabilitation.

Fuel tax revenues range from $20 to $21 million in 2003 under the Baseline Scenario.

The present system in the Ohio Region performed badly under both the High Coal Export and Miscellaneous Sensitivities Forecasts. Since the Miscellaneous Forecast generated the worst results it is discussed further with regard to Strategies III and IV. Both of these strategies would accommodate all tonnage and reduce delays and line-haul costs. This would be accomplished by constructing additional lock capacity. The largest number of new lock chambers built in this region is 13 chambers under Strategy IV. Most of these are built to either accommodate a 12' channel or to alleviate obsolescence. It is interesting to note that the deepening of the main stem of the Ohio increases tonnage throughput at locks substantially. In some cases this increase is enough to postpone further action beyond the time horizon of the study.

(h) Tennessee River

The evaluation of the present system found that:

1. Traffic increases sharply due in part to the completion of the Tennessee-Tombigbee Waterway.

2. Traffic in 2003 falls short of projected usage by less than two percent due to lock constraints in other regions.

3. Increased traffic and higher average tow sizes can increase the potential for new safety problems in the future.

Table V-23 presents the strategy evaluation measures for the Tennessee River. Projected usage is not accommodated entirely by Strategy I due to its failure to add capacity at constraining Ohio and Warrior River locks. Strategy II seeks to accommodate projected usage by "reallocating" resources to the Ohio and Warrior Rivers, but a small percentage of projected use is still not accommodated.

Average linehaul costs are lower under all four strategies than under the present system, because additional coal traffic, which moves at relatively low ton-mile costs, is handled.

Average delay and lock utilization show little or no change from the present system.

The main lock of interest in this region is the Kentucky Lock. This is the lowest lock on the Tennessee, located at mile 22. While this lock experiences high utilization, under most NWS forecasts the availability of an alternate routing through the Barkley Canal and Barkley Lock on the Cumberland, makes it unlikely that this lock would become constraining under the NWS criterion. Similarly, the 85% utilization rule for Strategy IV was relaxed somewhat in this case. Additional capacity would be added at this site by Strategy IV only under the High Use Scenario and under the sensitivity forecasts derived from the High Use Scenario.

Table V-23

Regional Evaluation Report for Tennessee River 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use (%)	99	99	99	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	10.4	10.4	10.3	10.1	10.1
Reduction in Linehaul Costs ($ Million)		0	1	4	4
Average Lock Delays (Hours per Tow)	1.5	1.5	1.5	1.5	1.5
Average Lock Utilization (%)	24	26	26	26	26
Locks Built	0	0	0	0	0
Safety Actions Taken	0	0	4	4	5
Public Expenditures 1977-2003 ($ Million)[2]	259	259	274	279	290
Fuel Tax Revenues ($ Million)[3]	N/A	3.3	3.3	2.8	2.8

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

[3]Receipts collected under P.L. 95-502 in 2003.

No safety actions are taken under Strategy I, despite the fact that this region is one of twelve with potential new safety problems in the future.

Safety actions are taken under the other three strategies. Four actions are taken to enhance vessel traffic services and install fenders and radar reflectors at bridges for Strategies II and III. A bridge is removed as an additional safety action under Strategy IV.

No expenditure reduction actions are taken under Strategy II; thus, Strategy II reallocates resources from

other waterways to meet the costs of safety actions in this region. Additional annual maintenance dredging is performed under Strategy IV. Accordingly, public expenditures are highest for Strategy IV.

Fuel tax revenues in 2003 are estimated to be $3 million.

(i) Arkansas River

The evaluation of the present system found that:

1. Lock capacity in this region is adequate to handle projected usage, however a small interaction with Locks and Dam 26 results in some diversion of traffic.

2. There is no reason to expect a significant increase in the potential for new safety problems.

Traffic is accommodated under three of the strategies due to the addition of a second 1,200' chamber at Locks and Dam 26 (see Table V-24). However, credit cannot be taken for traffic handled in 2003 under Strategy II. Under this strategy, federal support is withdrawn from the relatively high cost Class "C" segment (see Table IV-3). In sharp contrast to the preceding regions, federal funding is taken away entirely from this region and reallocated to fund lock expansion and safety enhancement actions throughout the rest of the system.

The rather drastic steps of withdrawing federal support is predicated upon the classification system described in Table IV-3. In the case of the Arkansas system this classification was subjected to a sensitivity analysis described in Section VI. That analysis showed that the "C" classification was sensitive to both cost projections and forecasts of projected use. The volume of dredging will likely be lower in the future as the system stabilizes. This is not captured in the NWS inventory and the analysis in Section IV. Traffic forecasts which are based on historical trend analysis, as are NWS forecasts, may not recognize the low base of traffic in the base period for a new waterway such as the Arkansas. Thus, the traffic projections upon which such a decision should be actually based should

Table V-24

Regional Evaluation Report for Arkansas River 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use (%)	99	100	0	99	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	16.9	16.9	NC	16.9	16.9
Reduction in Linehaul Costs ($ Million)		0	NC	0	0
Average Lock Delays (Hours per Tow)	1.3	1.3	NC	1.3	1.3
Average Lock Utilization (%)	30	30	NC	30	30
Locks Built	0	0	0	0	0
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	526	526	485	526	526
Fuel Tax Revenues ($ Million)[3]	N/A	1.3	NC	1.3	1.3

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

[3]Receipts collected under P.L. 95-502 in 2003.

be developed from more detailed studies. The sensitivity analysis in Section VI would reclassify the Arkansas as a "B" segment.

Linehaul costs show no change across all strategies since no direct actions were taken to improve service.

Average locks delays and lock utilization remain very low under all strategies during the study period.

No safety actions are taken under any strategy. The recent completion of the Arkansas in 1970 and the relatively low levels of traffic make this waterway safe for commercial transportation.

Public expenditures show no variation across the strategies with the exception of Strategy II. In 1995, federal funding of the White River project (classified as a side channel project for NWS Strategy II) is discontinued and, as previously discussed, the remaining federal funding for this region is withdrawn entirely in 2003.

Fuel tax revenues in 2003 are just over $1 million.

(j) Gulf Coast West

The evaluation of the present system found that:

1. No locks within the region constrain traffic growth, however interaction with Locks and Dam 26 did result in some traffic diversion.

2. Increases in traffic and high proportions of hazardous cargoes make this region one of twelve with potential new safety problems in the future.

The addition of a second chamber at Locks and Dam 26 results in the handling of projected usage under all four strategies. Harvey lock is replaced with a larger chamber as part of the replacement of obsolete locks under Strategy IV (see Table V-25). No other lock expansion actions are taken.

Average linehaul costs show little variation across the strategies except Strategy IV. Strategy IV's channel deepening actions on the Ohio, Illinois, and Mississippi Rivers permit operators to increase average barge ladings for all up-river traffic terminating or originating in the region. Since the GIWW West has sufficient depth to permit drafts greater than nine feet, no deepening actions within the region are required to obtain the linehaul cost reductions of Strategy IV. These reductions are estimated to be $55 million in 2003. Part of this reduction in linehaul costs is also attributable to the replacement of Harvey lock with a larger chamber.

This region includes a wide variety of navigation projects and its treatment under Strategies II and IV are

in sharp contrast. On the other hand, funds are diverted under Strategy II from the support of eleven side channels (requiring as much as four million cubic yards of average annual dredging) and seven minor ports (requiring as much as 2.6 million cubic yards of average annual dredging) to safety enhancement actions within the region as well as lock expansion and safety actions outside the region.

Table V-25

Regional Evaluation Report for Gulf Coast West in 2003[1] (Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	99	99	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	16.6	16.6	16.6	15.7	14.6
Reduction in Linehaul Costs ($ Million)[2]	N/A	0	0	25	55
Average Lock Delays (Hours per Tow)	0.2	0.2	0.2	0.2	0.1
Average Lock Utilization (%)	28	28	28	28	27
Locks Built	0	0	0	0	1
Safety Actions Taken	0	0	34	34	34
Public Expenditures 1977-2003 ($ Million)[3]	1,123	1,123	1,025	1,186	1,369
Fuel Tax Revenues ($ Million)[5]	N/A	8.2	8.2	8.2	8.2

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

Safety actions under Strategy II include installation of fenders and radar reflectors at 28 bridges and 2 locks as well as 3 actions to enhance vessel traffic services and a single action to improve navigation aids at a channel location. No safety actions can be taken under Strategy I despite the fact that this region is expected to have potential safety problems in the future.

On the other hand, Strategy IV seeks to reverse the historical decline in maintenance of authorized channel dimensions for this region. Over 4 million cubic yards of deferred maintenance dredging are undertaken each year beginning with 1990. In addition, the Port of Galveston is deepened to 50 feet. Three bridge alteration actions are taken to increase horizontal clearances as part of Strategy IV's safety program. Finally, the Harvey lock is replaced with a larger chamber. (It should be noted that no reduction in the linehaul costs of foreign traffic has been computed, despite the fact that the port deepening action can be expected to reduce the cost of grain exports and petroleum imports utilizing Galveston.)

Average lock delays and utilization are very low in this region throughout the study period.

Public expenditures for Strategies II and IV show a wide range, reflecting the very different treatment that this region receives under each strategy.

Fuel tax revenues in 2003 are estimated to exceed $8 million under P.L. 95-502.

(k) Gulf Coast East

The evaluation of the present system found that:

1. Lock capacity is adequate to accommodate projected usage and interaction with constraining locks in other regions is small.

2. Increasing traffic combined with mixture of deep and shallow-draft vessels, and a high proportion of hazardous cargoes may increase the potential for safety problems in the future.

Table V-26

Regional Evaluation Report
for Gulf Coast East in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	100	100	98	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	14.5	14.5	14.4	14.3	13.9
Reduction in Linehaul Costs ($ Million)[2]	N/A	0	1	1	4
Average Lock Delays (Hours per Tow)	0.4	0.4	0.4	0.4	0.1
Average Lock Utilization (%)	60	60	60	60	34
Locks Built	0	0	0	0	1
Safety Actions Taken	0	0	9	9	9
Public Expenditures 1977-2003 ($ Million)[3]	366	366	349	404	580
Fuel Tax Revenues ($ Million)[4]	N/A	3.4	3.2	3.4	3.2

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

Table V-26 presents the strategy evaluation measures. Projected use is accommodated except under Strategy II, where the Apalachicola, Chattahoochee, and Flint Rivers are no longer supported with federal funds after 1995. No lock expansion actions are taken except for the addition of a new chamber at Inner Harbor. As a result of this

action, linehaul costs (and lock delays) are reduced below those of the present system and private operators can expect to realize a modest reduction in annual operating costs of approximately $4 million in 2003.

Once again, the sharply different nature of navigation projects within this region make the outcomes under Strategies II and IV decidedly different. On the one hand, federal support of secondary ports and side channels is withdrawn in 1995 under Strategy II. In addition, the high cost, Class "C" segment in the region, namely the Apalachicola, Chattahoochee, and Flint Rivers, is no longer supported with federal funds after 1995. These funds are reallocated to improve safety within the region and to increase lock capacity and improve safety outside the region.

Safety actions are taken at five bridges and two channel locations. In addition, vessel traffic services are enhanced at two congested areas.

On the other hand, Strategy IV provides for the funding of annual deferred maintenance dredging of nearly seven million cubic yards. This dredging is split nearly equally between the New Orleans to Mobile and Mobile to St. Marks, Florida sections of the region.

Public expenditures differ sharply for Strategies II and IV.

Fuel tax revenues are just over $3 million annually in 2003 for all strategies under the Baseline Scenario.

There is only one lock of interest in this region, the Inner Harbor lock on the Gulf Intracoastal Waterway in New Orleans. Capacity is added to this lock by Strategies II and IV under various scenarios. Most importantly, if the data adjustment for this lock described in the Element K2 Report (Evaluation of the Present Navigation System) were taken into account in all the forecasts, this lock would be a candidate for capcity expansion under all strategy/scenario combinations.

(1) Mobile River and Tributaries

The evaluation of the present system found that:

1. Lock capacity is nearly adequate to accommodate projected use under the Baseline Scenario and inadequate under other scenarios.

2. New safety problems can be expected in the future due to increasing traffic, lock delays, and average tow size.

This region experiences fairly wide swings in its evaluation measures due to the large variances in the traffic forecasts, the presence of a major deep water port, and the presence of both "A" and "C" inland segments.

Table V-27 presents the strategy evaluation measures for the Baseline Scenario. No locks are expanded under Strategies I and II. However, traffic is nearly accommodated under both strategies. Neither Demopolis nor Oliver is expanded under Strategy II, because less than one million tons of projected grain and energy use are not accommodated in 2003. Since the Tombigbee-Warrior River is a Class "A" inland segment, lock capacity would be expanded under Strategy II in subsequent years.

Strategy II does relatively poorly in tons handled in 2003 as a result of the withdrawal of federal support for the Alabama-Coosa River.

Lock capacity at Demopolis and Oliver on the Warrior River is expanded under Strategies III and IV. These actions have positive impacts upon domestic linehaul costs and lock delays, and reduce average lock utilization. The domestic linehaul costs are lower under Strategy II due to the withdrawal of federal support for the relatively high cost Class "C" inland segment, the Alabama-Coosa, in 2000.

Linehaul costs are lowest (11.1 mills) under Strategy IV due not only to the construction of Demopolis and Oliver but also the widening of the Tombigbee-Warrior River to permit the passage of larger tows.

Table V-27

Regional Evaluation Report
for Mobile River and Tributaries 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	100	100	98	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	12.7	12.7	12.1	12.0	11.1
Reduction in Linehaul Costs ($ Million)[2]	N/A	0	13	15	34
Average Lock Delays (Hours per Tow)	3.5	3.5	3.6	1.8	1.8
Average Lock Utilization (%)	52	52	60	49	49
Locks Built	0	0	0	2	2
Safety Actions Taken	0	0	13	13	13
Public Expenditures 1977-2003 ($ Million)[3]	1,900	1,900	1,826	1,952	2,191
Fuel Tax Revenues ($ Million)[4]	N/A	4.0	3.5	3.6	3.6

NOTES: [1]All dollars are 1977 dollars.

[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003.

[4]Receipts collected under P.L. 95-502 in 2003.

No safety actions are taken under Strategy I, even though this region is one of twelve with potential new safety problems in the future. Minor structural actions are taken at ten bridges and three channel locations under Strategies II and IV. The safety actions are funded under Strategy II from the withdrawal of federal support for

minor ports in 1995 and the Alabama-Coosa in 2000. Thus, the region benefits from taking safety actions, but loses federal support of some navigation projects.

In sharp contrast to Strategy II, Strategy IV provides for a large increase in funding. The Port of Mobile is deepened to 55 feet at a cost of $458 million in 1990. In addition, the Tombigbee River south of Demopolis is widened to improve safety. Finally, over two million cubic yards of deferred maintenance dredging is undertaken each year after 1990.

Fuel tax revenues are estimated to be just over $3 million in 2003 for the Baseline Scenario.

Under other scenarios, the actions taken by the different strategies vary mainly in the number of additional lock chambers provided. This varies from none by Strategies I and II under the Low Use Scenario, to the addition of capacity at each site (6 locks) on the existing Tombigbee-Black Warrior system by Strategies III and IV under the High Coal Export forecast.

(m) South Atlantic Coast

The present system evaluation found that there is little reason to believe potential new safety problems will develop in the future due largely to the sharp decline in petroleum activity.

No actions are taken to reduce linehaul costs or improve safety under any strategy. However, once again, Strategies II and IV offer sharp contrasts. On the other hand, Strategy II withdraws federal support of minor ports and small side channels in 1995 (see Appendices A and B) and of the Atlantic Intracoastal Waterway from Miami to Norfolk in 2000. Thus, federal funds are clearly taken away from this region. As much as three million cubic yards of annual dredging for minor ports along the Carolinas are no longer funded by the federal government (see Exhibit IV-7 and Appendix A).

Table V-28

Regional Evaluation Report for South Atlantic Coast[1] (Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	2.4	2.4	2.4	2.4	2.4
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	1,209	1,209	1,148	1,209	1,291

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

On the other hand, over two million cubic yards of deferred maintenance dredging are undertaken along the Florida-Georgia coasts after 1990 under Strategy IV. Another 1.5 million cubic yards are undertaken each year along the Carolinas.

(n) Middle Atlantic Coast

The evaluation of the present system found, as in the case of the other Atlantic Coasts, that the decline in projected petroleum use offset most of the increases in projected use for coal, grain and other foreign trade. As a result, the potential for new safety problems in the future is not expected to increase significantly.

No safety actions are taken under the strategies. (This is true for the baseline scenario, but actions are taken under the High Use scenario for Strategies III and IV. See Exhibits IV-2 and IV-3 for a description of these

actions.) However, the Ports of Hampton Roads and Baltimore are deepened under Strategy IV as part of a major national effort to increase the competitiveness of United States grain and coal. Thus, a significant reduction in linehaul costs for foreign commerce can be expected.

As can be seen by Table V-29, Strategy II has the lowest public costs of any strategy. In 1995, federal support of side channels along the New York-New Jersey Coast is withdrawn along with the support of some minor ports. In 2000, federal support of the Atlantic Intracoastal Waterway is also withdrawn.

By way of contrast, under Strategy IV, deferred maintenance dredging of over five million cubic yards is undertaken in the Chesapeake and Delaware Bays and another two million cubic yards along the New York-New Jersey coast.

(o) North Atlantic Coast

Table V-30 presents the strategy evaluation measures for the North Atlantic Coast.

No safety actions are taken due to the decline in petroleum activity.

Under Strategy II, federal funding is cut back for the maintenance of deep-draft minor ports. No additional actions to reduce linehaul costs or increase channel reliability are taken under Strategy IV.

(p) Great Lakes-St. Lawrence Seaway-New York State Waterways

The evaluation of the present system found that substantial problems are expected to arise in Great Lakes/St. Lawrence Seaway traffic over the forecast periods. These problems include:

1. Lock capacity shortfalls at the Welland Canal section of the Seaway.

Table V-29

Regional Evaluation Report
for Middle Atlantic Coast in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	2.5	2.5	2.5	2.5	2.5
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	1,281	1,281	1,173	1,281	2,349

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

2. Increased delays at the St. Mary's River locks.

3. Increased potential for new safety problems in the future due to rising traffic and long lock delays.

4. A major shortfall of lock throughput capacity at the St. Mary's River Locks in 1990 under the Defense Scenario.

Capacity at the five constraining locks of the Welland Canal is assumed to be expanded by the Canadian government under all strategies (see Table V-31).

Table V-30

Regional Evaluation Report
for North Atlantic Coast in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	2.3	2.3	2.3	2.3	2.3
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	132	132	11	132	13227

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

No additional lock actions are taken under Strategies I-III. The more "generous" decision criterion for lock replacement under Strategy IV results in the construction of additional capacity at the United States owned St. Mary's River facilities.

The lock capacity additions under Strategy IV at the St. Mary's River result in an annual reduction in private operating costs of $40 million for 2003.

Lock delays and utilization, as might as be expected, decrease with each additional lock capacity action.

No safety actions are taken under Strategy I, even though the Great Lakes-Seaway is one of twelve regions where additional safety problems may develop in the future.

Table V-31

Regional Evaluation Report for Great Lakes-
St. Lawrence Seaway-New York State Waterways in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	100	100	98	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	3.0	3.0	3.0	2.8	2.7
Reduction in Linehaul Costs ($ Million)[2]	N/A	0	0	0	40
Average Lock Delays (Hours per Vessel)	6.8	3.1	3.1	3.1	1.2
Average Lock Utilization (%)	84	48	48	48	46
Locks Built	0	5	5	5	13
Safety Actions Taken	0	0	31	31	37
Public Expenditures 1977-2003 ($ Million)[3]	977	977	914	1,076	1,259

NOTES: [1]All dollars are 1977 dollars.

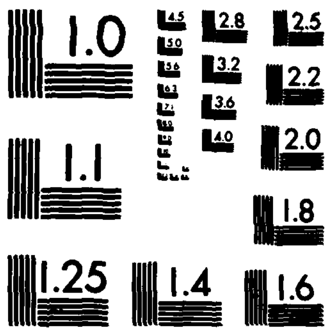
[2]Represents the product of projected ton-miles and the difference in 2003 linehaul costs between the present system and the modified system.

[3]Cumulative public expenditures for 1977-2003. These expenditures do not include the costs of adding lock capacity at the Welland Canal section of the St. Lawrence River Seaway. These costs are estimated to be $2 billion in 1981 dollars.

Strategies II and III take minor structural actions at 28 bridges and a channel location as well as two actions to enhance vessel traffic services. Strategy II reallocates funds for improving safety in this region by withdrawing federal support for minor ports and shallow-draft side channels within the region.

AD-A127 294 EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION 3/4
(U) KEARNEY (A T) INC CHICAGO ILL J EGAN ET AL. SEP 81
DACW72-79-C-0003

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Federal expenditures under Strategy IV are highest due to the construction of additional lock capacity at the St. Mary's River as well as the support of nearly one million cubic yards of deferred maintenance dredging each year beginning with 1990. The costs of the Canadian plan to increase the capacity of the Welland are estimated at $2 billion in 1981 dollars. These figures are not reflected in the costs in Table V-31.

The primary variation in strategies across scenarios is whether or not additional capacity is added at the St. Mary's River Locks and when it is needed. Since none of the Strategies would add capacity at this site early in the study period under peacetime conditions, all fail to provide capacity for defense emergency unless the defense emergency is anticipated. It should also be noted that the assumed construction period for an additional chamber at this site is five years. Initiation of construction at the onset of the hypothesized 5 year war would not meet the requirement on a timely basis.

(g) Washington-
Oregon Coast

Increased receipts of Alaskan oil as well as increased foreign trade make this coastal region one of the few with sizable gains during the period and with the potential for increased safety problems in the future.

Table V-32 shown on the following page presents the strategy evaluation measures. No safety actions are taken under Strategy I, even though there is potential for increased safety problems.

Minor structural actions at six bridges and a single action to enhance vessel traffic services in the Puget Sound are taken under Strategies II-III. These actions are shown in Exhibit IV-2. The funds for such actions

Table V-32

Regional Evaluation Report
for North Atlantic Coast in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	2.5	2.5	2.5	2.5	2.5
Safety Actions Taken	0	0	7	7	7
Public Expenditures 1977-2003 ($ Million)[2]	216	216	200	250	269

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

under Strategy II are obtained from withdrawing federal support of minor ports principally along the Washington-Oregon Coasts (see Appendix A).

Public expenditures are highest under Strategy IV due primarily to increased annual dredging along the Oregon-Washington Coasts.

(r) Columbia/Snake-Willamette River

The evaluation of the present system under the Baseline scenario found that there is adequate lock capacity to accommodate projected usage except for a possible major long-haul movement of sand and gravel from just north of Bonneville Lock and Dam to Portland.

No actions are taken to increase lock capacity except for Strategy IV. Under this strategy, capacity is added at Bonneville (see Table V-33).

Table V-33

Regional Evaluation Report for Columbia/Snake-Willamette in 2003[1] (Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	100	100	98	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	10.7	10.7	10.7	10.4	10.4
Average Lock Delays (Hours per Tow)	0.3	0.3	0.3	0.3	0.1
Average Lock Utilization (%)	22	22	22	22	20
Locks Built	0	0	0	0	1
Safety Actions Taken	0	0	31	31	37
Public Expenditures 1977-2003 ($ Million)[3]	457	457	427	469	456
Fuel Tax Revenue ($ Million)[3]	N/A	0.0	0.0	0.0	0.0

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

[3]Receipts collected under P.L. 95-502 are less than $100,000 in 2003.

Safety actions are taken under Strategies II and IV at a bridge and Bonneville. In addition, vessel traffic services are enhanced in the Portland area.

Under Strategy II, funds are taken from this region in order to improve safety and expand lock capacity in other regions. Federal support under this strategy is withdrawn for the Wilammette River navigation project above Portland.

By way of contrast, Strategy IV replaces an obsolete lock (rehabilitation costs are reduced as a result) and undertakes deferred maintenance dredging each year beginning with 1990.

This region is another region where the forecast of projected use was explicitly modified to take into account an alternative regional forecast provided by the Corps. This was done under the Miscellaneous Sensitivity forecast. Under that forecast Bonneville Lock constrained traffic and linehaul costs climbed to 11.7 mills per ton-mile in 2003 under the analysis of the present system. This constraint would be relieved by both Strategies III and IV.

(s) California Coast

The evaluation of the present system found that little increase in safety problems could be expected due in large part to the region's slow traffic growth. The increased receipts of Alaskan oil just offset the decline in imported oil.

No safety actions are taken under any strategy. Nor are actions taken to reduce linehaul costs (see Table V-34).

Funds are "reallocated" to other regions under Strategy II. Nearly six million cubic yards of dredging for side channels and minor ports are no longer supported with federal funds after 1995.

(t) Alaska

The large increase in domestic shipments of crude oil suggests that safety problems in the future may develop. As a result, actions to enhance existing vessel traffic services are made under Strategy I (see Table V-35).

Table V-34

Regional Evaluation Report
for California Coast in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	1.9	1.9	1.9	1.9	1.9
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	1,092	1,092	1,004	1,092	1,093

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

Since marine transportation is the primary source of transportation for some Alaskan villages, no attempt was made to identify minor ports or side channels in this region for withdrawal of federal support.

(u) Hawaii

Although imports of foreign oil decline, they are offset by increases in domestic traffic. Total projected use in this region is forecast to increase from 15.3 million tons in 1977 to 21.5 million tons in 2003 under the Baseline Scenario. No safety actions and no actions to reduce linehaul costs are taken (see Table V-36). Furthermore, since Hawaii is a group of islands, no attempt was made to identify side channels and minor harbors for possible withdrawal of federal support.

Table V-35

Regional Evaluation Report for Alaska in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	1.1	1.1	1.1	1.1	1.1
Safety Actions Taken	0	0	1	1	1
Public Expenditures 1977-2003 ($ Million)[2]	22	22	27	32	33

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

Table V-36

Regional Evaluation Report for Hawaii in 2003[1]
(Baseline Scenario)

	Present System	Strategy I	II	III	IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/ Ton-Mile)	3.0	2.9	2.9	3.0	3.0
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	10	10	10	10	10

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

(v) United States
Caribbean

Reduced oil imports are expected to reduce total traffic by 15 million tons in 2003. No basis for expecting an increase in safety problems was found as part of the evaluation of the present system.

Accordingly, no safety actions are taken under the strategies (see Table V-37). No actions are taken to reduce linehaul costs. And since this region is a group of islands, no attempt was made to identify minor ports and side channels for possible withdrawal of federal support.

Table V-37

Regional Evaluation Report for United States Caribbean in 2003[1] (Baseline Scenario)

	Present System	Strategy I	Strategy II	Strategy III	Strategy IV
Traffic Versus Projected Use					
Domestic (%)	100	100	100	100	100
Foreign (%)	100	100	100	100	100
Domestic Linehaul Costs (Mills/Ton-Mile)	2.3	2.3	2.3	2.3	2.3
Safety Actions Taken	0	0	0	0	0
Public Expenditures 1977-2003 ($ Million)[2]	12	12	12	12	12

NOTES: [1]All dollars are 1977 dollars.

[2]Cumulative public expenditures for 1977-2003.

SUMMARY

The national evaluation of the NWS strategies found that:

1. After completing the present system and funding its operation, maintenance, and rehabilitation, there are few discretionary funds available for improving it if a budget limit based on historical expenditures is adopted.

2. Projected use cannot be accommodated completely under Strategies I and II with budget limitations.

3. The differing schemes under Strategies I and II for allocating scarce public resources produce end results that differ by time period. Strategy I does a better job in 2003, but, in the long run beyond 2003, Strategy II does a better job of accommodating traffic.

4. In general, all strategies result in some reduction in private linehaul costs, but the greatest reduction in private costs are associated with the systemwide improvements of Strategy IV.

5. However, the reduction in average linehaul costs for Strategy IV is achieved at considerable public cost.

6. No funds are available for new safety actions under Strategy I even though 12 of the 22 regions can be expected to have new safety problems in the future.

The industry evaluation of the NWS strategies found that:

1. The agriculture and coal industries, the two industries most adversely affected by lock capacity shortfalls of the present system, enjoy an increase in traffic handled under all strategies.

2. In the short term, the withdrawal of federal support for the Arkansas under Strategy II results in the disappearance of some grain and coal flows. In the long run, Strategy II does a better job of adding capacity to key bottlenecks affecting these two industries.

The regional evaluation of the NWS strategies found that:

1. Additional traffic relative to Strategy I is accommodated under Strategy II for the Lower Upper Mississippi, Illinois, and Ohio Rivers. Conversely, additional traffic in 2003 is accommodated under Strategy I for the Lower Mississippi, Baton Rouge to Gulf, Arkansas, and Tombigbee-Warrior regions.

2. Linehaul costs are lower for Strategy II vis-a-vis Strategy I for the Upper Mississippi, Illinois, and Tombigbee-Warrior regions. The sharpest reductions in private operating costs are obtained by implementing the actions of Strategy IV.

LOCK ACTIONS TAKEN BY STRATEGY
(HIGH USE SCENARIO)

Region	Lock Name	Strategy I	Strategy II	Strategy III	Strategy IV
Primary Constraining Locks[1]					
2	Lock & Dam 26	X	X	X	X
7	Gallipolis		X	X	X
12	Demopolis			X	X
16	Welland Canal[2]	X	X	X	X
Secondary Constraining Locks[3]					
1	Lock & Dam 22			X	X
5	LaGrange		X	X	X[4]
5	Peoria			X	X[4]
5	Marseilles		X	X	X[4]
7	Uniontown		X	X	X
12	Warrior			X	X
12	Oliver[5]			X	X[6]
12	Holt			X	X
Congested Locks[7]					
1	Locks 16,20,21, 24 and 25				X[8]
1	Locks 17, 18 and 19				
2	Lock & Dam 27				
5	Starved Rock				X[4]
5	Dresden Island				X[4]
5	Lockport				X[4]
7	Newburgh				9
7	McAlpine				X[4]
7	Dashields				X[4]
7	Emsworth				X[4]
7	Montgomery			X	9
8	Kentucky				X
10	Harvey[5]				X
10	Algiers				
11	Inner Harbor[5]			X	X
12	Coffeeville			X	X
16	St. Mary's River			X	X
18	Bonneville[5]				X
Other Locks					
1	Lock 1[5]				X[6]
1	Lock 15				X[10]
5	Brandon Road				X[4]
7	L&D 52				X[4]
7	L&D 53				X[4]
7	Monongahela Locks 3, 4, 7 and 8[5]				X[6]
7	Winfield and Marmet Locks on the Kanawha[5]				X[6]
	TOTAL	6	11	21	44

NOTES:

[1]Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

[2]Locks 1, 2, 3, 7 and 8 are constraints and capacity is added to each.

[3]Constraining only if additional capacity is added at primary (controlling) locks.

[4]Action taken to accommodate 12' channel.

[5]Obsolete lock.

[6]Action taken to address lock obsolescence.

[7]Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[8]Locks 16, 20, 21, 24 and 25 are replaced to accommodate 10' channel.

[9]Delays are reduced by effect of deepening on lock capacity.

[10]Action taken to accommodate 10' channel.

LOCK ACTIONS TAKEN BY STRATEGY
(LOW USE SCENARIO)

Region	Lock Name	Strategy I	Strategy II	Strategy III	Strategy IV
Primary Constraining Locks[1]					
2	Lock & Dam 26	X	X	X	X
7	Gallipolis		X	X	2
12	Demopolis			X	X
16	Welland Canal[3]	X	X	X	X
Secondary Constraining Locks[4]					
5	LaGrange		X	X	X[5]
5	Marseilles		X	X	X[5]
12	Oliver[6]			X	X[7]
12	Holt			X	X
Congested Locks[8]					
1	Locks 20,21,22,24, and 25				X[9]
1	Lock 19				
5	Peoria			X	X[5]
5	Starved Rock				X[5]
5	Lockport				X[5]
7	Uniontown				10
7	McAlpine				X[5]
7	Emsworth				X
8	Kentucky				X
11	Inner Harbor[6]				X[7]
12	Warrior				X
12	Holt				X
16	St. Mary's River				
18	Bonneville[6]				X[7]
Other Locks					
1	Lock 16				X[7]
1	Lock 15				X[11]
5	Brandon Road				X[5]
6	Dresden Island				X[5]
7	L&D 52				X[5]
7	L&D 53				X[5]
7	Monongahela Locks 3, 4, 7 and 8[6]				X[7]
7	Winfield and Marmet Locks on the Kanawha[6]				X[7]
	TOTAL	6	9	12	38

NOTES: [1]Constraining locks that, unless expanded, restrict the amount of traffic to other locks.

[2]Capacity is expanded by effect of deepening, the constraint is relieved, and no further action is taken by this strategy.

[3]Locks 1, 2, 3, 7 and 8 are constraints and capacity is added.

[4]Constraining only if additional capacity is provided at primary (constraining) locks.

[5]Action taken to accommodate 12' channel.

[6]Obsolete lock.

[7]Action taken to address obsolescence.

[8]Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[9]Locks 16, 20, 21, 24 and 25 are replaced to accommodate 10' channel. Capacity is added at Lock and Dam 22 under 85% rule.

[10]Delays are reduced by effect of deepening on lock capacity.

[11]Action is taken to accommodate 10' channel.

LOCK ACTIONS TAKEN BY STRATEGY
(BAD ENERGY SCENARIO)

Region	Lock Name	Strategy I	Strategy II	Strategy III	Strategy IV
Primary Constraining Locks[1]					
2	Lock & Dam 26	X	X	X	X
7	Uniontown		X	X	X
12	Demopolis			X	X
16	Welland Canal[2]	X	X	X	X
Secondary Constraining Locks[3]					
1	Lock & Dam 22			X	X
5	LaGrange		X	X	X[4]
5	Peoria		X	X	X[4]
5	Marseilles		X	X	X[4]
12	Gallipolis		X	X	[5]
12	Oliver[6]			X	X[7]
Congested Locks[8]					
1	Locks 16,20,21,24, and 25				X[9]
1	Locks 17, 18, 19				
2	Lock & Dam 27				X[4]
5	Starved Rock				X[4]
5	Lockport				X[4]
7	Newburgh			X	[10]
7	Uniontown				[9]
7	McAlpine				X
7	Montgomery			X	[10]
7	Dashields				X[4]
7	Emsworth				X[4]
8	Kentucky				
10	Harvey[6]				X[7]
10	Algiers				
11	Inner Harbor[6]				X[7]
12	Warrior				X
12	Holt				X
16	St. Mary's River				X
18	Bonneville[6]				X[7]
Other Locks					
1	Lock 1[6]				X[7]
1	Lock 15				X[11]
5	Dresden Island				X[4]
5	Brandon Road				X[4]
7	L&D 52				X[4]
7	L&D 53				X[4]
7	Monongahela Locks 3, 4, 7 and 8[6]				X[7]
7	Winfield and Marmet Locks on the Kanawha[6]				X[7]
	TOTAL	1	11	16	42

NOTES:

[1] Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

[2] Locks 1, 2, 3, 7 and 8 are constraints and capacity is added to each.

[3] Constraining only if additional capacity is added at primary (controlling) locks.

[4] Action taken to accommodate 12' channel.

[5] Lock capacity is expanded by effect of deepening, the constraint is relieved, and no further action is taken.

[6] Obsolete lock.

[7] *Action taken to address lock obsolescence.*

[8] Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[9] Locks 16, 20, 21, 24, and 25 are replaced to accommodate 10' channel.

[10] Delays are reduced by effect of deepening on lock capacity.

[11] Action taken to accommodate 10' channel.

LOCK ACTIONS TAKEN BY STRATEGY (HIGH COAL EXPORTS FORECAST)

Region	Lock Name	Strategy I(1)	II(1)	III	IV
Constraining Locks[2]					
2	Lock & Dam 26			X	X
7	Gallipolis			X	X
7	Uniontown			X	X
12	Oliver[3]			X	X[4]
12	Demopolis			X	X
16	Welland Canal[5]			X	X
Potentially Constraining Locks[6]					
1	Lock and Dam 22			X	X
5	LaGrange			X	X[7]
5	Peoria			X	X[7]
5	Marseilles			X	X[7]
7	Newburgh			X	8
7	McAlpine			X	X[7]
11	Inner Harbor[3]			X	X[4]
12	Coffeeville			X	X
12	Holt			X	X
12	Warrior			X	X
12	Bankhead			X	X
Congested Locks[9]					
1	Locks 16,20,21,24 and 25				X[10]
1	Locks 17, 18, and 19				
2	Lock and Dam 27				
5	Starved Rock				X[7]
5	Dresden Island				X[7]
5	Lockport				X[7]
7	Dashields				X[7]
7	Emsworth				X[7]
7	Montgomery			X	11
8	Kentucky				X
10	Harvey[3]				X[4]
10	Algiers				
16	St. Marys River Locks			X	X
18	Bonneville[3]				X[4]
Other Locks					
1	Lock 1[3]				X[4]
1	Lock 15				X[12]
5	Brandon Road				X[7]
7	Lock and Dam 52				X[7]
7	Lock and Dam 53				X[7]
7	Lock and Dam 1 on Green River				X
7	Monongahela River Locks 3, 4, 7 and 8[3]				X[4]
7	Winfield and Marmet Locks on the Kanawha[3]				X[4]
	TOTAL			24	46

NOTES: [1]Not evaluated.

[2]Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

[3]Obsolete lock.

[4]Action taken to address obsolescence.

[5]Locks 1, 2, 3, 7, and 8 are constrained and capacity is added to each.

[6]Constraining only if additional capacity is added at constraining locks

[7]Action taken to accommodate 12' channel.

[8]Lock capacity is expanded by effect of deepening and the constraint is relieved.

[9]Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[10]Locks 16, 20, 21, 24 and 25 are replaced to accommodate 10' channel.

[11]Delays are reduced by effect of deepening on lock capacity.

[12]Action taken to accommodate 10' channel.

LOCK ACTIONS TAKEN BY STRATEGY (DEFENSE FORECAST)

Region	Lock Name	Strategy I(1)	Strategy II(1)	Strategy III	Strategy IV
Constraining Locks[2]					
2	Lock & Dam 26			X	X
7	Gallipolis			X	X
5	Marseilles			X	X[3]
12	Demopolis			X	X
16	Welland Canal[4]			X	X
16	St. Marys River Locks			X	X
Potentially Constraining Locks[5]					
1	Lock and Dam 22			X	X
5	LaGrange			X	X[3]
5	Peoria			X	X[3]
7	Uniontown			X	X
12	Warrior			X	X
12	Oliver[6]			X	X[7]
12	Holt			X	X
Congested Locks					
1	Locks 16,20,21,24 and 25				X[9]
1	Locks 17, 18, and 19				
2	Lock and Dam 27				
5	Starved Rock				X[3]
5	Dresden Island				X[3]
5	Lockport				X[3]
7	Newburgh				10
7	McAlpine			X	X[3]
7	Dashields				X[3]
7	Emsworth				X[3]
7	Montgomery			X	10
8	Kentucky				X
10	Harvey[6]				X[7]
10	Algiers				
11	Inner Harbor[6]			X	X[7]
12	Coffeeville			X	X
18	Bonneville[6]				X[7]
Other Locks					
1	Lock 1[6]				X[7]
1	Lock 15				X[11]
5	Brandon Road				X[3]
7	Lock and Dam 52				X[3]
7	Lock and Dam 53				X[3]
7	Monongahela River Locks 3, 4, 7 and 8[6]				X[7]
7	Winfield and Marmet Locks on the Kanawha[6]				X[7]
	TOTAL			21	44

NOTES: [1]Not evaluated.

[2]Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

[3]Action taken to accommodate 12' channels.

[4]Locks 1, 2, 3, 7, and 8 are constrained and capacity is added to each.

[5]Constraining only if additional capacity is added at constraining locks

[6]Obsolete lock.

[7]Action taken to address obsolescence.

[8]Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[9]Locks 16, 20, 21, 24 and 25 are replaced to accommodate 10' channel.

[10]Delays are reduced by effect of deepening on lock capacity.

[11]Action taken to accommodate 10' channel.

LOCK ACTIONS TAKEN BY STRATEGY
(MISCELLANEOUS ADJUSTMENTS FORECAST)

Region	Lock Name	Strategy I(1)	Strategy II(1)	Strategy III	Strategy IV
Constraining Locks[2]					
2	Lock & Dam 26			X	X
7	Gallipolis			X	X
11	Inner Harbor[3]			X	X[4]
12	Demopolis			X	X
16	Welland Canal[5]			X	X
18	Bonneville[3]			X	X[4]
Potentially Constraining Locks[6]					
1	Lock and Dam 22			X	X
5	LaGrange			X	X[7]
5	Peoria			X	X[7]
5	Marseilles			X	X[7]
7	Uniontown			X	X
7	Newburgh			X	8
7	McAlpine			X	X[7]
7	Montgomery			X	8
12	Warrior			X	X
12	Oliver[3]			X	X[4]
12	Holt			X	X
Congested Locks					
1	Locks 16,20,21,24 and 25				X[10]
1	Locks 17, 18, and 19				
2	Lock and Dam 27				
5	Starved Rock				X[7]
5	Dresden Island				X[7]
5	Lockport				X[7]
7	Dashields				X[7]
7	Emsworth				X[7]
8	Kentucky				X
10	Harvey[3]				X[4]
10	Algiers				
12	Coffeeville			X	X
16	St. Marys River				X
Other Locks					
1	Lock 1[3]				X[4]
1	Lock 15				X[11]
5	Brandon Road				X[7]
7	Lock and Dam 52				X[7]
7	Lock and Dam 53				X[7]
7	Monongahela River Locks 3, 4, 7 and 8[3]				X[4]
7	Winfield and Marmet Locks on the Kanawha[3]				X[4]
	TOTAL			11	44

NOTES: [1]Not evaluated.

[2]Constraining locks that, unless expanded, restrict the amount of traffic to other locks as well.

[3]Obsolete lock.

[4]Action taken to address obsolescence.

[5]Locks 1, 2, 3, 7, and 8 are constrained and capacity is added to each.

[6]Constraining only if additional capacity is added at constraining locks

[7]Action taken to accommodate 12' channel.

[8]Lock capacity is expanded by effect of deepening and the constraint is relieved.

[9]Locks with significant (60 minutes or more) increases in average tow or vessel delay.

[10]Locks 16, 20, 21, 24 and 25 are replaced to accommodate 10' channel.

[11]Action taken to accommodate 10' channel.

VI - SENSITIVITY ANALYSIS OF STRATEGIES

PURPOSE OF SECTION

The purpose of this section is to present a few brief sensitivity analyses as they relate to strategies. These sensitivities are concerned with how well the strategies perform against the three alternative sensitivity forecasts and the effects of adjustments to forecasts and cost data on the shallow draft segment classification scheme for Strategy II.

HIGH COAL EXPORT FORECAST

As described in the Element K2 Report (Evaluation of the Present Navigation System), one concern to be addressed as a sensitivity analysis was the performance of the present system and strategies if export coal movements were to increase more rapidly than in any of the basic scenarios. Accordingly a special forecast was prepared and the present system was evaluated against that forecast. The conclusion of that analysis was that additional locks would reach or exceed capacity by the year 2003 over and above even the High Use Scenario. These locks were:

1. McAlpine, Newburgh and Montgomery on the Ohio.

2. Bankhead and Coffeeville on the Tombigbee-Black Warrior System.

3. Inner Harbor on the Gulf Intracoastal Waterway East.

These constraints, combined with higher levels of delay in the affected regions also adversely affected linehaul cost.

This forecast was also checked against Strategy III to see when and if additional locks would be built under the 95 percent utilization criterion. As would be expected Strategy III would in fact build additional lock capacity at two additional sites. These are Newburgh on the Ohio

in 2003, and Bankhead on the Warrior in 2003. Although additional locks were found to be constraining for high coal exports, all of these except two would be taken care of by Strategy III. Other locks would be built earlier if Strategy III were applied to this forecast. These are:

1. Oliver, Warrior, Demopolis, and Coffeeville on the Tombigbee-Warrior System.

2. Inner Harbor on the Gulf Intracoastal Waterway East.

Thus there would be little difference in system capability by the year 2003 under Strategy III for this forecast. However, capability and the pattern of public expenditures during intervening years would be different.

Strategy IV would also build additional locks for this forecast compared to the High Use Scenario and build locks earlier. Strategies I and II would do an even poorer job of accommodating tonnage since more locks are constraining. Strategy II would probably also place greater emphasis on adding lock capacity in the Tombigbee-Warrior system at the expense of the Illinois Waterway.

DEFENSE

The defense analysis of the present system described in the Element K2 Report identified three locks as being constraints in 1990 under the postulated defense conditions. These were:

- St. Mary's River Locks on the Great Lakes.
- Gallipolis on the Ohio.
- Marseilles on the Illinois.

Since all the strategies tend to concentrate their actions to increase lock capacity towards the end of the study period, all strategies fail to deal with this particular emergency. Strategy IV would add capacity at Marseilles and Gallipolis in 1990 under the High Use Scenario, just as the emergency ends. Strategy IV would

not add capacity under the High Use Scenario at St. Mary's River, the most serious constraint, until the year 2000. Thus even the most generous strategy fails.

The principal conclusion is that management strategies designed to meet peacetime water transportation needs will not meet defense needs. This is due to the uncertain timing of defense needs. Obviously if it were possible to predict when the next major defense requirement would occur one could take this into account. Two of the defense constraints are also peacetime constraints and all strategies (except Strategy I) do deal with them sooner or later. However, the key defense constraint is dealt with only very late by both Strategies III and IV, and not at all by Strategies I and II.

If should also be pointed out that construction lead times for adding lock capacity would not permit a defense oriented strategy to wait until a conflict had begun. Defense readiness criteria would require construction in anticipation of requirements if the construction is to meet its objectives.

MISCELLANEOUS SENSITIVITIES

As discussed in the Element K2 Report (Evaluation of the Present Navigation System) a set of miscellaneous adjustments to basic traffic flow and forecast data were made to address various problems uncovered during the course of the integration process. These upward adjustments in projected use resulted in the following additional locks being found to be constraining over and above the constraints on the High Use Scenario:

1. Inner Harbor on the Gulf Intracoastal Waterway in 1985.

2. Bonneville Lock on the Upper Columbia in 1990.

3. McAlpine on the Ohio in 2000 (assuming that additional capacity is added at Gallipolis).

4. Montgomery on the Ohio in 2003 (assuming that additional capacity is added at Gallipolis).

In addition Gallipolis would become constraining 5 years earlier in 1995 than under the High Use Scenario.

Strategies III and IV would simply build these additional locks and build other locks earlier, much as under the High Coal Export Forecast. Strategies I and II perform little differently given the overall budget constraint. Strategy II may select different locks under this forecast.

SENSITIVITY OF STRATEGY II CLASSIFICATION SCHEME

As a result of concerns raised in the November 1980 public meetings two NWS Analytical Segments were reveiwed to see if adjustments to either public costs or projected use would result in a different classification for Strategy II, and a different priority for these segments.

(a) Upper Columbia-Snake Waterway (Segment 51)

This segment was classified as a Class B waterway for purposes of Strategy II. While there are no bases for adjusting the Operations and Maintenance Expenses for this segment, the Miscellaneous Sensitivities Forecast does provide a different forecast of traffic. Based on this higher level of activity the ratio of O&M Expense to ton-miles would be 0.0017, which would not result in the segment being reclassified.

(b) Arkansas-Verdigris-White Rivers (Segment 24)

This segment was also examined under the Miscellaneous Sensitivities forecast. Dredging volumes are also expected to decline from 3.3 million cubic yards annually to 2.6 million cubic yards. This long term reduction is expected to occur as this new system stablizes. The higher traffic levels and reduced costs were also examined in combination

with the Baseline Scenario and baseline costs to see if the segment would change its classification. This analysis is summarized in Table VI-1.

The numbers in the body of Table VI-1 are recomputed ratios, in the year 2003 followed by the resulting classification. As can be seen, the projected cost reduction alone would not be sufficient to change the classification under Baseline Scenario forecasts of projected use. Computing the ratio using High Use Scenario forecasts and reduced costs yields a ratio of 0.0048, low enough to justify reclassification as a B segment.

Table VI-1

Sensitivity Analysis of
Arkansas-Verdigris-White Rivers

	Ratio of O&M Expenses to Project Ton-miles ($/TM)	
Traffic Levels	Baseline	Adjusted
Baseline Scenario	0.0055 (C)	0.0051 (C)
High use Scenario	0.0052 (C)	0.0048 (B)
Increased Under Miscellaneous Sensitivity Forecast	0.030 (B)	0.0028 (B)

The overall effect of reclassification of this segment on Strategy II would be to shift funds from construction in other regions to continued operations and maintenance on the Arkansas. The general direction of change of the various evaluation measures for Strategy II would shift back more towards Strategy I as a result.

ENVIRONMENTAL SENSITIVITIES

The detailed environmental sensitivity analysis is presented in Appendix E. This analysis focussed on variations in costs the "implementability" of actions under "more strict" and "less strict" environmental policies. The conclusions of that analysis are:

1. Environmental policies will have more direct affects on the cost of dredging than on the cost of other actions.

2. Baseline environmental policies and less strict policies will generally allow most actions to take place, with the probable exception of some deepening actions.

3. More strict environmental policies will allow operation and maintenance of the present system, but will drastically curtail other actions.

4. Strategies I and II would be strongly affected by future environmental policies. The higher costs imposed by more strict policies will cause these strategies to fail to meet basic needs of the system under the postulated real budget constraint. Conversely, less strict policies will postpone the day of reckoning. Strategy II in particular will find it possible to meet most of the needs of the "A" and "B" system and avoid withdrawal of federal support from the higher ranked "C" segments under some scenarios.

5. Strategy IV will be strongly affected by future environmental policies. Only under a less strict set of policies would it become likely that all the channel and port deepening actions included in Strategy IV be likely to be implemented.

VII - CONCLUSIONS

This section summarizes seven conclusions regarding the evaluation of the NWS strategies. These conclusions are stated below.

1. Strategies subject to constant dollar budget limits based on recent historical federal expenditure levels (let alone in federal support) must make hard choices about allocation of scarce resources.

2. Strategies subject to such budget limits for federal expenditures cannot accommodate all projected usage.[1] Such strategies based on meeting water transportation needs without regard to establishing priorities for expenditure will in the long run result in a poorer overall performance.

3. Overall levels of expenditures vary more widely with level of service to water transportation set as a strategic objective than with levels of commerce per se. This results from the finding that a large and growing portion of waterway expenditures is for operations, maintenance, and rehabilitation of the present system, which retains a high priority under all strategies.

4. The private operating costs of major waterway industries such as agriculture and coal are reduced by taking carefully selected actions.

5. No strategy as applied to the four peacetime NWS scenarios adds capacity to the St. Mary's River locks except late in the study period. Since these locks were found to be a major constraint to waterway traffic for the steel industry under a defense emergency, the strategies do not perform well with regard to defense considerations.

6. The environmental evaluation of strategies varied little across scenarios. The major effects evaluated in Appendix C concern dredging. Thus strategies which vary dredging volumes will generate different levels of impacts. The other major variation across strategies arises in Strategy I, which fails to take any safety actions.

---

[1]Waterway cost sharing is an alternative option for funding water transportation needs. The impacts of alternative user charges are presently being studied by the Department of Transportation.

7. The environmental sensitivity analysis in Appendix E found the strategies and their associated costs to be sensitive to different environmental policies. The major effects of environmental policies are felt in dredging costs and dredging actions.

GLOSSARY OF TERMS

Backhaul: The movement of barges or vessels on a return trip from destination to origin for another load. Backhaul trips can be empty or loaded with a different cargo for at least part of the trip.

Barge: A non-self-propelled, usually flat-bottomed vessel, used for carrying freight on inland waterways.

Beam: The width of a vessel at its widest point.

Capability: For NWS, water transportation capability is the ability of the present navigation system to handle commercial navigation safely and at a linehaul cost consistent with the historical cost relationship among the transportation modes.

Capacity: The ability of a lock or channel to handle commercial navigation measured in tons during a year.

Chamber: The part of a lock enclosed by the walls, floor, sills, and gates; the part of a lock within which the water level is changed as vessels are raised or lowered. A lock may have more than one chamber, and they may be adjacent or laterally separated.

Channel Maintenance: Dredging, lighting and other operations which ensure or maintain the navigability of a channel.

Cubic Yard: The volume enclosed in a cubic space whose linear dimensions are one yard.

Draft: The depth to which the hull of a vessel or barge is submerged.

Horsepower: A unit of power equal to 746 watts. Approximately 550 foot pounds per second.

Integration: The NWS study process of evaluation of the present navigation system, and application and evaluation of strategies.

Intracoastal Waterway: Inland route paralleling the coast for inland craft.

Jumbo Barge: A barge 195 feet long and 35 feet wide.

Lock: A structure on a waterway equipped with gates so that the level of the water can be changed to raise or lower vessels from one level to another.

Lockage: Passage of a tow or other vesssel through a lock. A normal lockage cycle consists of an approach, entry, chambering, and exit.

Lockage Time: The time elapsed from the start of approach of the first vessel or cut served by a lockage to the end of exit of the last vessel or cut served by a lockage. Includes the time required to dissassemble and assemble multiple-cut tows and to rearrange set-over tows, when such activities prevent the use of the lock by other vessels.

Navigation Season: That part of the year when the waterway is open to traffic.

Non-Structural Measure: Proposed measure to improve navigation on a waterway or segment not involving building of a lock nor any structural modifications to the lock or waterway.

O & M: Operation and Maintenance.

One Way Reach: A reach narrow enough that two vessels may not pass simultaneously.

Open Pass: Passage of a vessel through a lock with no lock hardware operation. This is possible only when the upper and lower pool levels are nearly equal, and occurs most frequently at tidal locks.

PMS: Performance Monitoring System. The Corps of Engineers system for keeping and producing statistics at locks. It is not applied uniformly at all locks.

Practical Lock Capacity: For NWS integration purposes, practical lock capacity is defined as 90% of theoretical capacity.

Projected Use: A forecast of waterborne commodity flows that can be expected to use water transportation without regard to constraints.

Public Cost: The amount of resources (measured in dollars) expended by government agencies. For NWS integration purposes, public costs are confined to federal expenditures, primarily by the Corps of Engineers.

Reach: A channel segment between two given points on a waterway.

Representative Lock: A lock designated as representative of locks of similar size.

Reliability: Refers to the percentage of time a facility is in use or able to be used.

River Mile: A number specifying the location of a point along a waterway, obtained as the distance from a reference point designated as mile zero.

Scenario: Assumptions about uncontrollable events affecting the use or performance of the navigation system.

Standard Barge: A barge 175 feet long and 26 feet wide.

Strategy: A set of policies and directives for taking actions to meet water transportation needs.

Ton: A unit of weight equal to 2,000 pounds avoirdupuis (907.20 kilograms); short ton.

Ton-Mile: A unit of transportation production equal to the movement of one ton a distance of one statute mile.

Tow: A towboat and one or more barges which are temporarily fastened together and operated as a single unit.

Towboat: A shallow-draft commercial vessel used to push or pull barges.

Tow Configuration: Orientation of barges tied together to form a tow.

Traffic: As used in the evaluation of the present system and strategies in NWS, traffic refers to tons of projected use actually accommodated.

APPENDIX A

BREAKDOWN OF DREDGING DATA

EXPLANATION OF APPENDIX

This appendix contains the base year annual dredging data used in the analysis of strategies. Late in the conduct of NWS integration numerous errors were found in the NWS inventory. The data used in this report were not adjusted to correct for these errors due to the lateness with which the changes were received. The data in the tables in this appendix have been footnoted to give the correct values.

The projects recorded in the NWS Inventory were classified into shallow draft and deep draft categories based on controlling depths published in the 1977 Waterborne Commerce Statistics. Any controlling depth of 15 feet or less was considered shallow draft.

Table A-1 shows the average annual volumes and the unit costs. Table A-2 shows the average annual costs assigned to the various waterway categories.

Table A-1

BREAKDOWN OF DREDGE VOLUMES
(100 c.y.)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft	Unit Cost ($/c.y.)
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois Waterway						B	26,226[1]	1,065	27,291[2]	27,291[2]	$1.003[3]
2. Lower Upper Mississippi	2. Lower Upper Mississippi, Illinois Waterway to Missouri R.						A	(4)		(4)	(4)	(5)
	3. Middle Mississippi Missouri R. to Ohio R.						A	57,960	2,426	60,386	60,306	0.524
3. Lower Mississippi	4. Lower Middle Mississippi Ohio R. to White R.						A	220,000[6]		220,000[6]	220,000[6]	0.263[7]
	5. Upper Lower Mississippi White R. to Old R.						A	109,211[8]		109,211[8]	109,211[8]	0.232[9]
	6. Lower Mississippi, Old River to Baton Rouge						A	14,805		14,805	14,805	0.600
4. Baton Rouge to Gulf	7. Mississippi R., Baton Rouge to New Orleans	57,223		1,223		58,446					58,446	0.342
	8. Mississippi R. New Orleans to Gulf	445,683		30,214		475,897					475,897	0.433
	25. Ouachita, Black[10] and Red Rivers						C	24,494		24,494	24,494	0.519
	26. Old and Atchafalaya Rivers			51,073		51,073	C	1,146		1,146	52,219	0.270
	27. GIWW Port Allen Route						A	6,350		6,350	6,350	0.465

Table A-1

BREAKDOWN OF DREDGE VOLUMES
(100 c.y.)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft	Unit Cost ($/c.y.)
5. Illinois Waterway	9. Illinois Waterway						A	25,124		25,124	25,124	0.681
6. Missouri River	10. Missouri River						B	44,911(11)	3,573	48,484(12)	48,484(12)	0.829(13)
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha R.						A	1,800	108	1,908	1,908	2.558
	12. Middle Ohio, Kanawha R. to Kentucky R.						A	4,010	3,265	7,275	7,275	1.185
	13. Lower Ohio Three, Kentucky R. to Green R.						A	4,666		4,666	4,666	0.849
	14. Lower Ohio Two, Green R to Tennessee R.						A	9,660		9,660	9,660	1.128
	15. Lower Ohio One, Tennessee R to Mouth						A	20		20	20	1.000
	16. Monongahela R.						A	710		710	710	2.972
	17. Allegheny R.						B	400(14)		400(14)	400(14)	2.775(15)
	18. Kanawha R.						A	96	14	110	110	5.000
	19. Kentucky R.						C	1,100		1,100	1,100	1.082
	20. Green R.						A	750		750	750	1.293
	21. Cumberland R.						B	892		892	892	2.029

Table A-1

BREAKDOWN OF DREDGE VOLUMES
(100 c.y.)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft	Unit Cost ($/c.y.)
8. Tennessee River	22. Upper Tennessee and Clinch Rivers Head of Navigation to Junction with Tennessee Tombigbee Waterway						A					
	23. Lower Tennessee, Junction with Tennessee Tombigbee to Mouth						A	300		300	300	1.733
9. Arkansas River	24. Arkansas, Verdigris, White and Black Rivers						C	24,881	8,061	32,942	32,942	0.735
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu R.			4,487	130	4,617	A	15,039	21,911	36,950	41,567	0.701
	29. GIWW West Two, Calcasieu R., to Corpus Christi	16,212(16)	15,399(17)	313,698(18)	2,641(19)	347,950	A	73,740(20)	8,442(21)	82,182	430,132	0.314
	30. GIWW West Three, Corpus Christi to Brownsville	27,250		11,035	11,750	50,035	A		540	540	50,575	1.066
	34. Houston Ship Channel		586(22)	76,392(23)	6,862(24)	83,840		308(25)	3,312(26)	3,620	87,460	0.535
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile			37,889(27)	3,926(28)	41,815	A	2,583(29)	1,280(30)	3,863	45,678	0.521
	32. Mobile to St. Marks, Fla.			2,383	5,205	7,588	B	9,188	528	9,716	17,304	0.751

Table A-1

BREAKDOWN OF DREDGE VOLUMES
(100 c.y.)

NWS Region	NWS Segment	Deep Draft Through Channels	Deep Draft Side Channels	Deep Draft Major Ports	Deep Draft Minor Ports	Deep Draft Total	Segment Class	Shallow Draft Through Channels	Shallow Draft Side Channels	Shallow Draft Total	Segment Total of Deep and Shallow Draft	Unit Cost ($/c.y.)
11. Gulf Coast East	33. Florida Gulf Coast			16,580		16,580					16,580	2.025
	38. Apalachicola, Chattahoochee, and Flint Rivers						C	17,015		17,015	17,015	0.746
12. Mobile River and Tributaries	35. Black Warrior - Mobile Harbor			38,601	1,645	40,246	A	23,549	48	23,597	63,843	0.515
	36. Alabama and Coosa Rivers						C	16,344		16,344	16,344	0.386
	37. Tennessee-Tombigbee[31] Waterway						A					
13. South Atlantic Coast	39. Florida-Georgia Coast			79,776[32]	31,633[33]	111,409[34]	C	6,005[35]	2,381[36]	8,386[37]	119,795[38]	0.819[3]
	40. Carolinas Coast			113,987[40]	30,873[41]	113,987[42]	C	53,641[43]	3,141[41]	53,641[45]	167,628[46]	0.939[47]
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	35,040[48]		17,511[49]	4,618	57,169[50]	C	1,415[51]	353	1,768[52]	58,937[53]	2.018[54]
	42. New Jersey - New York Coast	5,120	8,832	23,745	4,362	42,059	C	2,266	13,364	15,630	57,689	2.061
15. North Atlantic Coast	44. Upper Atlantic, New York-Connecticut Boundary to St. Croix R., Maine	730		3,820	3,179	7,729			492	492	8,221	3.050

Table A-1

BREAKDOWN OF DREDGE VOLUMES
(100 c.y.)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft	Unit Cost ($/c.y.)
16. Great Lakes, St. Lawrence Seaway	43. New York State[55] Waterways											
	45. Lake Ontario and St. Lawrence Seaway		98	1,131	3,034	4,263					4,263	1.208
	46. Lake Erie			38,878	3,984	42,862			58	58	42,920	1.375
	47. Lake Huron	3,553		2,411	1,200	7,164					7,164	7.581
	48. Lake Michigan			7,801	5,402	13,203			240	240	13,443	2.067
	49. Lake Superior			1,764	544	2,308					2,308	2.409
17. Washington-Oregon Coast	50. Puget Sound		860	5,180		6,040					6,040	1.250
	53. Oregon-Washington Coast			44,213	17,589	61,802					61,802	0.805
18. Columbia Snake Waterway	51. Upper Columbia-Snake Waterway						B					
	52. Lower Columbia-Snake Waterway	131,000				131,000		3,316	65,599	68,915	199,915[56]	0.378[56]
19. California Coast	54. Northern California	8	1,022	3,390	328	4,748					4,748	1.264
	55. San Francisco Bay	28,259		27,503	2,177	57,939		1,500[57]	0[58]	1,500	59,439	1.630[59]
	56. Central-South California		18,404	70,520	12,139	101,063					101,063	1.817
20. Alaska	57. Southeast Alaska											
	58. South Central Alaska	825				825					825	2.994

Table A-1

BREAKDOWN OF DREDGE VOLUMES
(100 c.y.)

NWS Region	NWS Segment	Deep Draft Through Channels	Deep Draft Side Channels	Deep Draft Major Ports	Deep Draft Minor Ports	Deep Draft Total	Shallow Draft Segment Class	Shallow Draft Through Channels	Shallow Draft Side Channels	Shallow Draft Total	Segment Total of Deep and Shallow Draft	Unit Cost ($/c.y.)
20. Alaska	59. West and North Coasts of Alaska	110			110						110	4.545
21. Hawaii Territories	60. Western Pacific			1,518(60)	(61)	1,518					1,518	1.357
22. Caribbean	61. Caribbean			2,050(62)	(63)	2,050					2,050	1.410
TOTAL		751,013	45,201	1,028,773	122,348	1,947,335		805,421	137,060	942,481	2,889,816	

SOURCES: Corps of Engineers, NWS Inventory, IWR Letter dated 29 May, 1981.

FOOTNOTES:

1. Correct value is 25,185.
2. Correct value is 26,253.
3. Correct value is 1.018.
4. Correct value is 638.
5. Correct value is 1,003.
6. Correct value is 303,133.
7. Correct value is 0.273.
8. Correct value is 120,641.
9. Correct value is 0.231.
10. Data shown do not include projected maintenance dredging for the Red River project. This is estimated to be 840,000 cubic yards annually and is added to the volumes shown upon the assumed completion date.
11. Correct value is 6,266.
12. Correct value is 9,839.
13. Correct value is 0.979.
14. Correct value is 219.
15. Correct value is 5.068
16. Correct value is 15,000.
17. Correct value is 36,450.
18. Correct value is 290,250.
19. Correct value is 6,250.
20. Correct value is 62,200.
21. Correct value is 19,982.
22. Correct value is 640.
23. Correct valuie is 75,700.
24. Correct value is 7,500.
25. Correct value is zero.
26. Correct value is 3,620.
27. Correct value is 37,925.
28. Correct value is 3,890.
29. Correct value is 2,593.
30. Correct value is 1,270.

31. There was no dredging on this segment during the period that the inventory was compiled. A value of 140,000 cubic yards annually priced at $0.849 was applied when the segment was assumed to be opened. More recent information indicates that 1,800,000 cubic yards should have been used.

32. Correct value is 117,407.

33. Correct value is 1,700.

34. Correct value is 119,107.

35. Correct value is 8,369.

36. Correct value is 1,231.

37. Correct value is 9,600.

38. Correct value is 128,707.

39. Correct value is 0.765.

40. Correct value is 81,541.

41. Correct value is 30,873.

42. Correct value is 112,414.

43. Correct value is 50,410.

44. Correct value is 3,141.

45. Correct value is 53,551.

46. Correct value is 165,965.

47. Correct value is 0.949.

48. Correct value is 67,434.

49. Correct value is 33,700.

50. Correct value is 105,752.

51. Correct value is 2,859.

52. Correct value is 3,212.

53. Correct value is 19,291.

54. Correct value is 1.095.

55. The NWS inventory records 1,929,100 cubic yards of dredging for the New York State Waterways.

56. According to information provided on May 29, 1981, the correct total for this segment is 13,300,000 c.y. and the correct unit cost is $0.420 per cubic yard. However, the information provided is not sufficient to provide correct numbers for the allocation.

57. Correct value is zero.

58. Correct value is 1,500.

59. Correct value is 0.760.

60. Correct value is 938.

61. Correct value is 580.

62. Correct value is 2,000.

63. Correct value is 50.

Table A-2

BREAKDOWN OF DREDGE COSTS
($1,000)

WWS Region	WWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois Waterway							2630	107	2737	2737
2. Lower Upper Mississippi	2. Lower Upper Mississippi, Illinois Waterway to Missouri R.										
	3. Middle Mississippi, Missouri R. to Ohio R.							3037	127	3164	3164
3. Lower Mississippi	4. Lower Middle Mississippi, Ohio R. to White R.							5786		5786	5786
	5. Upper Lower Mississippi, White R. to Old R.							2534		2534	2534
	6. Lower Mississippi, Old River to Baton Rouge							888		888	888
4. Baton Rouge to Gulf	7. Mississippi R., Baton Rouge to New Orleans	1957		42		1999					1999
	8. Mississippi R. New Orleans to Gulf	19298		1308		20606					20606
	25. Ouachita, Black and Red Rivers							1271		1271	1271
	26. Old and Atchafalaya Rivers			1379		1379		31		31	1410
	27. GIWW Port Allen Route							295		295	295

Table A-2

BREAKDOWN OF DREDGE COSTS
($1,000)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft
5. Illinois Waterway	9. Illinois Waterway							1711		1711	1711
6. Missouri River	10. Missouri River							3723	296	4019	4019
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha R.							460	28	488	488
	12. Middle Ohio, Kanawha R. to Kentucky R.							475	387	862	862
	13. Lower Ohio Three, Kentucky R. to Green R.							396		396	396
	14. Lower Ohio Two, Green R. to Tennessee R.							1090		1090	1090
	15. Lower Ohio One Tennessee R. to Mouth							2		2	2
	16. Monongahela R.							211		211	211
	17. Allegheny R.							111		111	111
	18. Kanawha R.							48	7	55	55
	19. Kentucky R.							119		119	119
	20. Green R.							97		97	97
	21. Cumberland R.							181		181	181

Table A-2

BREAKDOWN OF DREDGE COSTS
($1,000)

NWS Region	NWS Segment	Deep Draft					Shallow Draft				Segment Total of Deep and Shallow Draft
		Through Channels	Side Channels	Major Ports	Minor Ports	Total	Segment Class	Through Channels	Side Channels	Total	
8. Tennessee River	22. Upper Tennessee and Clinch Rivers, Head of Navigation to Junction with Tennessee Tombigbee Waterway										
	23. Lower Tennessee, Junction with Tennessee Tombigbee to Mouth							52		52	52
9. Arkansas River	24. Arkansas, Verdigris, White and Black Rivers							1829	592	2421	2421
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu R.			315	9	324		1054	1536	2590	2914
	29. GIWW West Two, Calcasieu R., to Corpus Christi	509	484	9850	83	10926		2315	265	2580	13506
	30. GIWW West Three, Corpus Christi to Brownsville	2905		1176	1253	5334			58	58	5392
	34. Houston Ship Channel		31	4087	367	4485		16	177	193	4678
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile			46	205	251		135	67	202	453
	32. Mobile to St. Marks, Fla.			179	391	570		690	40	730	1300

Table A-2

BREAKDOWN OF DREDGE COSTS
($1,000)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft
11. Gulf Coast East	33. Florida Gulf Coast			3357		3357					3357
	30. Apalachicola, Chattahoochee, and Flint Rivers							1269		1269	1269
12. Mobile River and Tributaries	35. Black Warrior - Mobile Harbor			1988	85	2073		1213	2	1215	3288
	36. Alabama and Coosa Rivers							631		631	631
	37. Tennessee-Tombigbee Waterway										
13. South Atlantic Coast	39. Florida-Georgia Coast			6534	2591	9125		492	195	687	9812
	40. Carolina Coast			10703		10703		5037		5037	15740
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	7071	0	3534	932	11537		285	71	356	11893
	42. New Jersey-New York Coast	1055	1820	4894	899	8668		467	2754	3221	11889
15. North Atlantic Coast	44. Upper Atlantic, New York-Connecticut Boundary to St. Croix R., Maine	223		1165	970	2358			150	150	2508

Table A-2

BREAKDOWN OF DREDGE COSTS
($1,000)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft
16. Great Laes, St. Lawrence Seaway	43. New York State Waterways										0
	45. Lake Ontario and St. Lawrence Seaway		12	137	367	516					516
	46. Lake Erie			5346	548	5894			8	8	5902
	47. Lake Huron	2694		1828	910	5432					5432
	48. Lake Michigan			1612	117	2729			50	50	2779
	49. Lake Superior			425	131	556					556
17. Washington-Oregon Coast	50. Puget Sound		108	648		756					756
	53. Oregon-Washington Coast			3559	1416	4975					4975
18. Columbia-Snake Waterway	51. Upper Columbia-Snake Waterway										0
	52. Lower Columbia-Snake Waterway	4952				4952		125	2480	2605	7557
19. California Coast	54. Northern California	1	129	428	41	599					599
	55. San Francisco Bay	4605		4483	355	9443		245		245	9688
	56. Central-South California		3344	12813	2206	18363					18363
20. Alaska	57. Southeast Alaska										
	58. South Central Alaska	247				247					247

Table A-2

BREAKDOWN OF DREDGE COSTS
($1,000)

NWS Region	NWS Segment	Deep Draft					Shallow Draft				Segment Total of Deep and Shallow Draft
		Through Channels	Side Channels	Major Ports	Minor Ports	Total	Segment Class	Through Channels	Side Channels	Total	
20. Alaska	59. West and North Coasts of Alaska	50				50					50
21. Hawaii and Pacific Territories	60. Western Pacific			206		206					206
22. Caribbean	61. Caribbean			289		289					289
TOTAL		45567	5928	82331	14876	148702		40951	9397	50348	199050

SOURCES: Corps of Engineers, NWS Inventory, IW Letter dated 29 May, 1981.

APPENDIX B

BREAKDOWN OF OTHER OPERATIONS AND MAINTENANCE EXPENSES

EXPLANATION OF APPENDIX

This appendix contains the base year annual costs for "other operations and maintenance" used in the analysis of strategies. Late in the conduct of NWS integration numerous errors were found in the NWS inventory. The data used in this report were not adjusted to correct for these errors due to the lateness with which the changes were received.

The data in the table in this appendix have been footnoted to give the correct values.

The projects recorded in the NWS Inventory were classified into shallow draft and deep draft categories based on controlling depths published in the 1977 Waterborne Commerce Statistics. Any controlling depth of 15 feet or less was considered shallow draft.

Table B-1

Breakdown of Other Operations and Maintenance Expenses
($1,000)

		Deep Draft					Shallow Draft				Segment Total
NWS Region	NWS Segment	Through Channels	Side Channels	Major Ports	Minor Ports	Total	Segment Class	Through Channels	Side Channels	Total	of Deep and Shallow Draft
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois Waterway						B	21,541	51	21,592	21,592
2. Lower Upper Mississippi	2. Lower Upper Mississippi, Illinois Waterway to Missouri R.						A	2,964		2,964	2,964
	3. Middle Mississippi, Missouri R. to Ohio R.						A	3,376	570	3,946	3,946
3. Lower Mississippi	4. Lower Middle Mississippi, Ohio R. to White R.						A	5,232		5,232	5,232
	5. Upper Lower Mississippi, White R. to Old R.						A	1,137	540	1,677	1,677
	6. Lower Mississippi, Old River to Baton Rouge						A	633		633	633
4. Baton Rouge to Gulf	7. Mississippi R., Baton Rouge to New Orleans	70		522		592					592
	8. Mississippi R. New Orleans to Gulf	1,040		2,194		3,234					3,234
	25. Ouachita, Black and Red Rivers						C	1,496		1,496	1,496(1)
	26. Old and Atchafalaya Rivers						C	465		465	465
	27. GIWW Port Allen Route						A	343		343	343

Table B-1 (Continued)

Breakdown of Other Operations and Maintenance Expenses
($1,000)

		Deep Draft					Shallow Draft				
NWS Region	NWS Segment	Through Channels	Side Channels	Major Ports	Minor Ports	Total	Segment Class	Through Channels	Side Channels	Total	Segment Total of Deep and Shallow Draft
5. Illinois Waterway	9. Illinois Waterway						A	3,153		3,153	3,153
6. Missouri River	10. Missouri River						B	3,622		3,622	3,622
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha R.						A				
	12. Middle Ohio, Kanawha R. to Kentucky R.						A				
	13. Lower Ohio Three, Kentucky R. to Green R.						A	9,317(2)		9,317(2)	9,317(2)
	14. Lower Ohio Two, Green R to Tennessee R.						A				
	15. Lower Ohio One, Tennessee R to Mouth						A				
	16. Monongahela R.						A				
	17. Allegheny R.						B				
	18. Kanawha R.						A				
	19. Kentucky R.						C	2,132		2,132	2,132
	20. Green R.						A	860		860	860
	21. Cumberland R.						B	3,038		3,038	3,038

Table B-1 (Continued)

Breakdown of Other Operations and Maintenance Expenses
($1,000)

		Deep Draft						Shallow Draft			
NWS Region	NWS Segment	Through Channels	Side Channels	Major Ports	Minor Ports	Total	Segment Class	Through Channels	Side Channels	Total	Segment Total of Deep and Shallow Draft
8. Tennessee River	22. Upper Tennessee and Clinch Rivers, Head of Navigation to Junction with Tennessee Tombigbee Waterway						A				
	23. Lower Tennessee, Junction with Tennessee Tombigbee to Mouth						A	2,980		2,980	2,980
9. Arkansas River	24. Arkansas, Verdigris, White and Black Rivers						C	12,568(3)	(4)	12,568	12,568
10. Gulf Coast West	28. GIWW West One, New Orleans to Calcasieu R.			580(5)	(6)	580	A	1,966(7)	(8)	1,966	2,546
	29. GIWW West Two, Calcasieu R., to Corpus Christi			335		335	A	263		263	598
	30. GIWW West Three, Corpus Christi to Brownsville						C				
	34. Houston Ship Channel										
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile			368	49	417	A	139	90	229	646
	32. Mobile to St. Marks, Fla.			31(9)	149(10)	180	B	1,171	15	1,186	1,366

Table B-1 (Continued)

Breakdown of Other Operations and Maintenance Expenses
($1,000)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft
11. Gulf Coast East	33. Florida Gulf Coast			152		152		772(11)	565(12)	1,337	1,489
	38. Apalachicola, Chattahoochee, and Flint Rivers						C	1,674		1,674	1,674
12. Mobile River and Tributaries	35. Black Warrior - Mobile Harbor			871	37	908	A	2,242	5	2,247	3,155
	36. Alabama and Coosa Rivers						C	701		701	701
	37. Tennessee-Tombigbee Waterway(13)						A				
13. South Atlantic Coast	39. Florida-Georgia Coast			622(14)		622(14)	C	1,797(15)	1,039(16)	2,836(17)	3,458(18)
	40. Carolinas Coast		(19)	1,643(20)	(21)	1,643(22)	C	1,929(23)	341(24)	2,270(25)	3,913(26)
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	3,247		858(27)	359(28)	4,464	C	1,505		1,505	5,969
	42. New Jersey - New York Coast			3,217(29)	20(30)	3,237		1,508	992	2,500	5,737
15. North Atlantic Coast	44. Upper Atlantic, New York--Connecticut Boundary to St. Croix R., Maine	200		10	69	279			126	126	405

Table B-1 (Continued)

Breakdown of Other Operations and Maintenance Expenses
($1,000)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Shallow Draft: Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total and Shallow Draft
16. Great Lakes, St. Lawrence Seaway	43. New York State Waterways										
	45. Lake Ontario and St. Lawrence Seaway		150(31)	297(32)	49(33)	496					496
	46. Lake Erie			1,596(34)	173(35)	1,769			1,014	1,014	2,783
	47. Lake Huron	4,426		155	67	4,648					4,648
	48. Lake Michigan		(36)	879(37)	240(38)	1,119					1,119
	49. Lake Superior			134	80	214			38	38	252
17. Washington-Oregon Coast	50. Puget Sound							1,025		1,025	1,025
	53. Oregon-Washington Coast	45				45					45
18. Columbia-Snake Waterway	51. Upper Columbia-Snake Waterway						B	3,045		3,045	3,045
	52. Lower Columbia-Snake Waterway										
19. California Coast	54. Northern California										
	55. San Francisco Bay	420		200		620		150(39)	(40)	150	770
	56. Central-South California			10		10					10
20. Alaska	57. Southeast Alaska	296(41)				296(41)					296(41)
	58. South Central Alaska	(42)				(42)					(42)

Table B-1 (Continued)

Breakdown of Other Operations and Maintenance Expenses
($1,000)

NWS Region	NWS Segment	Deep Draft: Through Channels	Deep Draft: Side Channels	Deep Draft: Major Ports	Deep Draft: Minor Ports	Deep Draft: Total	Segment Class	Shallow Draft: Through Channels	Shallow Draft: Side Channels	Shallow Draft: Total	Segment Total of Deep and Shallow Draft
20. Alaska	59. West and North Coasts of Alaska										
21. Hawaii and Pacific Territories	60. Western Pacific										
22. Caribbean	61. Caribbean	—	—	47	—	47		—	—	—	47
TOTAL		9,744	150	14,721	1,292	25,907		94,744	5,386	100,130	126,037

SOURCE: Corps of Engineers, NWS Inventory.

NOTES:

[1] Does not include expenses for the Red River project. These are set at $2,650,000 and are charged when the project is expected to be completed. Expenses for entire main stem of Ohio River (Segments 11, 12, 13, 1' and 15).

[2] Correct value is 12,493.

[3] Correct value is 12,493.

[4] Correct value is 75.

[5] Correct value is 233.

[6] Correct value is 347.

[7] Correct value is 1,477.

[8] Correct value is 1,477.

[9] Correct value is 43.

[10] Correct value is 137.

[11] Correct value is zero.

[12] Correct value is 1,337.

[13] Projected costs of $6,360,000 are included for the Tennessee-Tombigbee Waterway upon completion.

[22] Correct value is 1,507.

[23] Correct value is 1,725.

[24] Correct value is 342.

[25] Correct value is 2,067.

[26] Correct value is 3,574.

[27] Correct value is 903.

[28] Correct value is 314.

[29] Correct value is 2,000.

[30] Correct value is 1,237.

[31] Correct value is 380.

[32] Correct value is 49.

[33] Correct value is 59.

[34] Correct value is 1,720.

[35] Correct value is 49.

[36] Correct value is 61.

APPENDIX C

ENVIRONMENTAL EVALUATION OF STRATEGY ACTIONS

INTRODUCTION

The purpose of this appendix is to summarize the generic environmental impacts associated with the actions included in NWS Strategies I through IV.

The level of detail varies from action to action. This is reflective of the quantity and quality of the available literature. The literature is indicative of actions with large environmental impacts. Nearly one half of this appendix is devoted to dredging and dredged material disposal.

The discussion of the environmental impacts of actions is organized by major categories of actions. The ten major side headings are:

- Comparison of Strategies.
- Dredging and Dredged Material Disposal.
- River Training.
- Lock Operation.
- Lock Rehabilitation.
- Actions to Increase Lock Capacity.
- Minor and Nonstructural Actions.
- Channel Deepening/Widening.
- Port Deepening.
- Summary of Generic Impacts.

COMPARISON OF STRATEGIES

The purpose of this brief discussion is to present a summary comparison of the environmental effects of the different strategies based upon the analysis presented subsequently in this appendix. The most important variations in the strategies which are of concern here are

variations in maintenance dredging, safety actions, lock construction, and channel deepening and widening. The variations in these actions are summarized in Table C-1 below:

Table C-1

Variations in Actions Across Strategies

Action	Strategy I	Strategy II	Strategy III	Strategy IV
Maintenance Dredging	Baseline Volumes	Reduced Volumes	Baseline Volumes	Increased Volumes
Safety Actions (1)	0	188	191	200(2)
Lock Construction (range in number of actions across scenarios)	6	9-11	12-24	38-46
Channel Deepening and Widening	None	None	None	Some(3)

Notes: (1) Baseline Scenario only. Strategy I never funds any safety actions. The maximum number of safety actions is 200.

(2) Some major structural actions are substituted for minor actions under Strategy IV.

(3) See Exhibit IV-4 for detailed descriptions.

Maintenance dredging is a major component of total costs and is a major action for each strategy. To the extent that aggregate volumes are indexes of impacts, then Strategy II has less effect on the environment and Strategy IV has the greatest impact. However, it must be emphasized that there are major qualitative differences in effects of dredging in differnet areas. Interested readers can find additional details in the NWS Element M Report (Analysis of Environmental Aspects of Waterways Navigation). It should also be pointed out that the cost

projections for future dredging requirements incorporate allowances for meeting current environmental requirements, as discussed in Section IV of this report.

Safety actions are important because they tend to reduce the likelihood of accidents when they occur. This in turn reduces the environmental effects of cargo spills, fires, etc. Since Strategy I funds no safety actions it clearly is the poorest performer in this area. The other three strategies fund high levels of safety actions and would tend to do better in this area than Strategy I. Strategy IV also substitutes some major structural actions to enhance safety for some minor actions, thus incurring some additional environmental effects, primarily during construction.

Lock construction by itself is not considered to have major widespread environmental effects. Since Strategy IV builds the largest number of locks, it would generate more effects associated with this type of action.

Channel deepening and widening would have significant environmental effects, particularly in channels and/or ports where polluted bottom sediments would be disturbed. Thus, Strategy IV, the only strategy which incorporates these actions, would have more serious effects in this area than the other strategies.

DREDGING AND DREDGED MATERIAL DISPOSAL

(a) Introduction

One of the important impacts common to both dredging and disposal of dredged material is increased levels of turbidity and suspended sediment. Turbidity and suspended sediment are addressed separately. Following this are separate discussions of dredging impacts and dredged material disposal impacts.

(b) Turbidity and Suspended Sediment

1. Definition. Turbidity is a result of the presence of suspended material such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Collectively these particles interfere with the transmission of light through a liquid medium. Confusion concerning turbidity is a result of the multiplicity of definitions, units of measure, and methods of measurement, many of which are not equivalent or interchangeable (Stern and Stickle, 1978). Differences in measurement are due to the type, shape, and size of the sediment particles, the organic content, and water characteristics (COE, 1975).

2. Origins. Dredging and dredged material disposal are not the only sources of turbidity and suspended material. They are the results of both natural processes and other human activities. Land erosion, primarily as a result of agricultural activities, is the greatest cause of turbidity in most lakes, rivers, and estuaries in the United States, with about 500 million short tons of sediment carried into the sea each year (Stern and Stickle, 1978). The resuspension of bottom sediments as a result of wave action, prop wash, currents, and winds is also an important source of turbidity. Additional sources of turbidity include construction, bank erosion, dredging, biological sources (plankton blooms, red tides, organic detritus, and the foraging of aquatic animals), and the discharge and disposal of various wastes such as dredged materials, industrial wastes, and sewage and sewage sludge.

3. Impacts. It is often difficult to assess the effects of turbidity and suspended material on aquatic organisms. Other conditions frequently affect aquatic organisms before and during the increase in turbidity and suspended solids, such as changes in temperature and dissolved oxygen. Laboratory experiments often do not duplicate natural conditions or reflect natural levels of tolerance. Several investigators have demonstrated that suspensions of dredged material which affected organisms in the laboratory produced no detectable changes when encountered in the same concentrations in nature. In other studies, higher concentrations of resuspended natural sediments were required to cause the same effects obtained

with suspensions of processed mineral solids of known composition, particle size distribution, and organic matter content (Stern and Stickle, 1978).

In addition, most of the literature points out the importance of knowing the source of turbidity. Viewed in this regard, dredging-induced turbidity can be placed in perspective relative to other sources such as sewage disposal, storm runoff, logging operations, road construction, farming, and mining. These sources generally produce chronic turbidity rather than the discrete resuspensions of sediments from dredging operations. In addition, natural phenomena such as wind and waves cause large quantities of sediment to become suspended and to remain so for long periods of time, mainly in shallow water. However, the chemical nature of wind-wave suspended sediments is different than dredged sediments particularly in terms of their oxidation-reduction potential. Dredged sediments are typically more reduced, thus can cause oxygen reductions and influence metal transfer reactions. The abrasion and physical impacts caused by the two types of sediments, however, would be similar (COE, 1975).

Dredging-induced turbidity can be severe in the immediate area of operation, and some of the finest particles can be dispersed over considerable distances. However, within a few hours after cessation of dredging or disposal operations, turbidity generally declines to background levels. Therefore, it can not usually be stated that the effects of turbidity found in studies which used exposure times of several days, weeks, or months are the same as the effects of dredging-induced turbidity. Caution must be exercised to relate levels of turbidity and duration of exposure in studies to those that would be expected in the field (COE, 1975).

(a) Water Quality. A number of reactions (sorption, precipitation, flocculation, and aggregation) are of ecological importance. They function in the absorption, transportation, and desorption of heavy and trace metals, pesticides, and nutrients in fresh and estuarine waters.

The release of nutrients can be both beneficial (release valuable nutrients) and detrimental (simulate biological

growth such as algal blooms and red tides) (Stern and Stickle, 1978).

Another water quality parameter that is affected by turbidity and suspended materials is dissolved oxygen. Most field monitoring studies adjacent to dredging operations have revealed depressions of oxygen content of the receiving waters. These conditions were usually found only near the bottom near the point of discharge and were of short duration as a result of rapid mixing of dredging and disposal site water and the surrounding water (Stern and Stickle, 1978). Slotta et al. (1974) feel that oxygen depletion caused by dredging induced suspended sediment is not a problem under most estuarine conditions.

(b) Primary Production. Numerous studies have examined the effects of turbidity and suspended material on the development of phytoplankton populations. The most frequently cited negative aspect is the reduced photosynthetic activity due to the interference of light penetration. However, the addition of suspended material can also stimulate photosynthesis by increasing the available nutrients (Stern and Stickle, 1978).

(c) Invertebrates (Stern and Stickle, 1978). Many species of the phylum Mollusca, particularly the members of the class Bivalvia (clams, oysters, mussels), are filter feeders and play an important role in reducing turbidity by removing suspended materials from the water column. Because bivalves are more or less stationary, they frequently respond to increased levels of turbidity and suspended sediment by tightly sealing their valves. Thus they may survive adverse conditions for several days by avoiding direct contact with the surrounding water.

Among members of the phylum Arthropoda, the most closely studied species have been those in the class Crustacea (crabs, lobsters, shrimp, barnacles). The effects of turbidity and suspended sediments on the species of crustaceans studied to date are highly variable. For several species of adult copepods, suspensions of fuller's earth, silica sand, and natural sediments in combination with suspensions of phytoplankton caused reductions in feeding rates because the zooplanktons were unable to feed selectively. Suspended sediment concentrations also reduced the ability to molt through various larval stages.

(d) Fish. Turbidity and suspended material affects fishes directly and indirectly. Recent data, based upon weight and volume concentrations of suspended solids from several closely monitored laboratory studies, are probably more indicative of the natural responses of adult fishes to suspended solids. The results of these studies have indicated that adult fishes as well as invertebrates are affected by a complex interaction between suspended solids, temperature, and dissolved oxygen. Although the lethal concentration at which ten percent of the individuals will be killed (LC_{10}) is known, it is not possible to predict the magnitude of the LC_{20}, LC_{50}, etc. A correlation exists between normal habitat and sensitivity to suspended solids. High suspended solids concentrations would be less harmful in winter than in summer, and fishes as a group are more sensitive to suspended solids than many of the invertebrates studied to date (Stern and Stickle, 1978).

The extent of interference is dependent upon the type of gills or filtering apparatus used. Plankton feeding fish characteristically have long, thin gill

rakers which are easily clogged by sediment particles. Bottom dwelling fish are more adapted to turbid conditions and do not possess gill modifications. However, almost any type of gill can become covered with silt, impeding the passage of oxygen to the fish, and preventing normal loss of waste material from the gill surface. Gill tissue may also become thickened from long exposure to high turbidity.

(e) Bioaccumulation. Release of sediment-associated heavy metals and their uptake into organism tisues has been found to be the exception rather than the rule. Results demonstrate there is little or no correlation between bulk analysis of sediments for heavy metals content and their environmental impact.

(c) Dredging Impacts

1. Water Quality and Aquatic Habitat. By their action, dredges cause a variety of negative impacts to the water quality and aquatic ecosystem. They include:

(a) Changed habitat in dredged area.

(b) Removal of benthic organisms and the shellfish beds.

(c) Increased levels of turbidity and suspended solids.

(d) Release of heavy metals, nutrients and other pollutants from resuspended material.

(e) Biological uptake of released pollutants.

(f) Covering of benthic organisms by sediments.

Items (a, b, and c), are addressed in the following three sections. The impact of turbidity and suspended solids (c) in addition to the release of pollutants (d)

and biological uptake (e) were addressed in the preceding section. The covering of benthic organisms by sediment (f) is only a minor impact associated with dredging. Depending upon the disposal method used, however, it can be a significant impact associated with dredged material disposal and is addressed further later on.

Investigators have noted that the actual intensity, duration, and area influenced by sediment-water interactions are greater during open water disposal (Sustar et al., 1976) and, storms (Sustar et al., 1976; Slotta et al., 1974) than during dredging, per se. Increases in suspended solid levels during dredging are confined basically to the channel, whereas increases at disposal sites often influence areas outside the site boundaries. The influence of storms is even more widespread.

Investigators have noted positive impacts associated with dredging also. Information from Herbich (1975) indicates that dredging can have advantageous effects on the aquatic environment by removing polluted bottom sediments for safe storage and/or treatment, reoxygenating sediments and the water column through mixing; resuspending nutrients making them available to suspension feeders; and removing dissolved and particulate pollutants from the water column by absorption and resettling. Gustafson (1972) also detailed the beneficial effects of dredging. Bacteria attack sewage substances much more readily when the substances are attached to clay rather than dispersed within the water, as long as the clay remains suspended. Turbid waters also offer shelter and protection to larval and immature life which use bay waters as nursery ground.

(a) Changed Habitat in Dredged Area. Removal of bottom material to deepen channels changes the aquatic habitat in several ways. It:

1. Alters hydraulic conditions (i.e. flow velocities and volumes).

2. Exposes different substrate material.

Changes in current regimes may alter sediment composition, water quality, established patterns (spatially and temporally) of erosion and sedimentation, and/or create a loss of food sources.

Channelization of estuaries produces changes in hydraulic conditions which may alter the function of reserve populations by changing the transport patterns of the larval stages.

Slotta et al. (1974) found that there was a decrease in median grain size at the dredge sites they investigated due to exposure of fine subsurface material. Obviously the extent of such differences will vary from site to site.

(b) Removal of Benthic Organisms and Shellfish Beds. That dredging disrupts the benthic habitat at the excavation site is obvious (Hirsch et al., 1978). The substrate and associated organisms at the dredge site are removed for disposal elsewhere.

The removal of significant number of benthic infauna from the dredged channel areas creates an environment of depleted biological activity. The percentage of organisms removed is proportional to the intensity of the dredging activity which includes the number of passes in a shoal area by a dredge and the frequency of maintenance over a long-term period (COE, 1975). On a short-term basis, studies (cited in COE, 1975) of a dredged channel in Chesapeake Bay indicated that hydraulic pipeline dredging had removed up to 72% of the benthic organisms in some areas. Observations in Coos Bay, Oregon of channels dredged with a hopper dredge indicated removal was between 74 to 88%. Other studies at Moss Landing Harbor (Monterey County) indicated that with a clamshell dredge, benthic organism removal in some areas approaches 100%.

Even though a large percentage of bottom life may be removed, it has been shown by many investigators that dredged channels repopulate rapidly after cessation

of the dredging operation. In Coos Bay, total faunal abundance returned to pre-dredging levels in 14 to 28 days. In Mobile Bay, Alabama, recovery in terms of numbers in a channel area took less than six months. Dredging sampling conducted by the Corps of Engineers in the San Francisco Main Ship Channel Bar study also noted an increase in the number of species and number of organisms during the recovery period.

It should be noted that the frequency with which a river channel may require dredging is highly variable and usually specific to a particular river or river segment. Such factors as the rate of sedimentation, river and areal physiography, river current patterns and age contribute to the rate of dredging activity. Generally speaking, river channels typically require dredging every one to five years, thereby allowing benthic organisms time to recover and reestablish.

Though repopulation appears to be very rapid in dredged channels, recovery (in terms of the reestablishment of a community similar to that which inhabited the area prior to dredging) may take considerable longer than just a few months. Observations in Mobile Bay show that areas influenced by dredging do not generally return to what may be considered a normal condition for a period of at least two years. The studies at Moss Landing noted that, even after 1-1/2 years, the recolonized harbor area was completely different in terms of species number, composition, number of individuals, species diversity, evenness and trophic dominance. Channel areas that are dredged frequently (i.e., every one to three years) may never develop faunal assemblages similar to those found in comparable environments not subject to periodic disturbances.

(c) Turbidity and Suspended Sediment. Under a given set of environmental conditions, different types of dredges will generate different levels of turbidity. While the dredging equipment certainly has a large effect on the amount and concentration of sediment that is resuspended, the techniques for operating this equipment are also important.

Although operator training and performance may be one of the most important factors controlling turbidity generation, it is often difficult to evaluate the various parameters of a dredge's operation that reflect the skills of the operator. Unfortunately, turbidity levels are typically measured with little regard to the operation of the dredges on their rates of production (Barnard, 1978).

The most widely studied dredges are the clamshell, hopper, and cutterhead dredges. Depending on the above factors, clamshell or bucket dredges might be generally expected to create plumes in the water column with suspended solids concentrations not exceeding 0.5 grams per liter (g/l) and with average concentration probably less than 0.1 g/l (Barnard, 1978). Hydraulic cutterhead or pipeline dredges generally do not create suspended solids levels in excess of a few hundred milligrams per liter (mg/l) in the water column near the dredging site. Hopper dredges probably do not create water column suspended solids concentrations in excess of 1 g/l over any appreciable area of the dredging site (Barnard, 1978). In addition, the levels are intermittent as the hopper dredge moves between dredging and disposal sites, often with a cycle time of an hour or more (Peddicord & McFarland, 1978).

2. Wetlands and Terrestrial Habitat. Dredging has an insignificant impact on terrestrial habitat. The only impact to wetlands is small and occurs indirectly as a function of changes in water quality.

3. Impact Variation by Type of Dredge.

(a) Grab/Bucket/Clamshell Dredges. The grab, bucket, or clamshell dredge is operated from a crane or derrick mounted on a barge (Huston, 1970). It is used extensively for removing relatively small volumes of material (i.e., a few tens or hundreds of thousands of cubic meters) particularly around docks and piers or within other restricted areas. The sediment is removed at nearly its in site density; however; production rates (relative to a cutterhead dredge) are low, especially in consolidated material. The material is usually placed in barges or scows for transportation to the disposal area. Although the dredging depth is practically unlimited, the deeper the depth the lower the production rate. In addition, the clamshell dredge usually leaves an irregular, cratered bottom (Barnard, 1978).

The turbidity generated by a typical clamshell operation can be traced to four major sources. Most of this turbidity is the result of sediment resuspension occurring when the bucket impacts on and is pulled off the bottom. Also, because most buckets are not covered, the "surface" material in the bucket and the material adhering to the outside of the bucket are exposed to the water column as the bucket is pulled up through the water column. When the bucket breaks the water surface, turbid water may spill out of the bucket or may leak through openings between the jaws. In addition to inadvertent spillage of material during the barge loading operation, turbid water in the barges is often intentionally overflowed (i.e.,

displaced by higher density material) to increase the barge's effective load (Barnard, 1978).

To minimize the turbidity generated by a typical clamshell operation, the Port and Harbor Research Insitute of Japan developed a watertight bucket with edges that seal when the bucket is closed. In addition, the top of the watertight bucket is covered so that the dredged material is totally enclosed within the bucket. Available sizes range from 2 to 20 cubic meters.

A direct comparison of typical bucket and watertight bucket clamshell operation indicates that watertight buckets generate 30 to 70% less turbidity in the water column than the typical buckets. This reduction is probably due primarily to the fact that leakage of dredge material from watertight buckets is reduced by approximately 35% (Yagi et al., 1977).

(b) Hopper Dredges. In those areas characterized by heavy ship traffic or rough water, a self-propelled hopper dredge would probably be used. During a hopper dredge operation, as the dredge moves forward, the bottom sediment is hydraulically lifted from the channel bottom through a draghead, up the dragarm (i.e., trailing suction pipe), and temporarily stored in hopper bins in the ship's hull. Most modern hopper dredges have one or two dragarms mounted on the side of the dredge and have storage capacities ranging from several hundred to over 9,000 cu. meters. The hoppers are either emptied by dumping the dredged material through doors in the bottom of the ship's hull or by direct pumpout through a pipeline (Huston, 1970; Herbich, 1975).

Resuspension of fine-grained dredged material during hopper dredge operations

is caused by the dragheads as they are pulled through the sediment, turbulence generated by the vessel and its prop wash, overflow of turbid water during hopper filling operations, and dispersion of dredged material during open-water disposal (Barnard, 1978).

The most obvious source of near-surface turbidity is the overflow water. During the filling operation, dredged material slurry is often pumped into the hoppers after they have been filled in order to maximize the amount of higher density material in the hopper. The lower density, turbid water at the surface of the filled hoppers overflows and is usually discharged through ports located near the waterline of the dredge. Distributions of suspended solids in these overflow plumes are primarily dependent on the nature, concentration, and volume of overflow ports; and the hydrologic characteristics of the dredging site (such as water depth, salinity, and current direction and velocity). Although there may be no increase in the hopper load achieved by continued pumping of fine-grained sediment into filled hoppers (Thorn, 1975; deBree, 1977), overflowing is a common practice.

Level of suspended solids in a plume generated by typical hopper dredge overflow can be decreased by reducing the solids concentration of the overflowed material (Barnard, 1978). This can be accomplished by reducing the flow rate of the slurry being pumped into the hoppers during the latter phases of the hopper filling operation (DeBree, 1977). By using this technique, the solids content of the overflow can be decreased substantially (e.g. from 200 to 100 g/l or less by weight) while the loading efficiency of the dredge is simultaneously increased.

(c) <u>Cutterhead Dredges</u>. The cutterhead dredge is the most commonly used dredge in the United States. With this type of dredge, a rotating cutter at the end of a ladder excavates the bottom sediment and guides it into the suction. The excavated material is picked up and pumped by a centrifugal pump to a designated disposal area through a 15 cm (6 in) to 112 cm (44 in) pipeline as a slurry with a typical solids content of 10 to 20% by weight. The nominal size of the dredge is usually defined by the diameter of its discharge pipeline. For conventional cutterhead dredges, the diameter of the cutter is approximately three to four times the diameter of the suction pipe. The typical cutterhead dredge is swung in an arc from side to side by alternately pulling on port and starboard swing wires connected to anchors through pulleys mounted on the ladder just behind the cutter. Pivoting on one of two spuds at the stern, the dredge "steps" or "sets" forward. Although the cost of mobilizing a cutterhead dredge is relatively high, its operation is nearly continuous and production rates (i.e., cubic meters of material dredged per hour) are generally high (Huston, 1970; Herbich, 1975).

Most of the turbidity generated by a cutterhead dredging operation (exclusive of dispoal) is usually found in the vicinity of the cutter (Huston & Huston, 1976). The levels of turbidity are directly related to the type and quantity of material cut, but not picked up by the suction. The amount of material supplied to the suction is controlled primarily by the rate of cutter rotation, the vertical thickness of the dredge cut, and the swing rate of the dredge (i.e., the horizontal velocity, of the cutter moving across the cut). The ability of the dredge's suction to pick up this bottom material determines

the amount of cut material that remains on the bottom or suspended in the water column. In addition to the dredging equipment used and its mode of operation, turbidity may also be caused by sloughing of material from the sides of vertical cuts, inefficient operational techniques, and the prop wash from the tenders (tugboats) used to move pipeline, anchors, etc., in the shallow water areas outside the channel (Barnard, 1978). From his review, Barnard (1978) concluded that the turbidity generated around the cutter of a cutterhead dredge apparently increases exponentially as the thickness of the cut, rate of swing, and cutter rotation rate increase. Although suspended solid levels around the cutter also increase with increasing rate of production, it is possible to maximize the production rate of the dredge without resuspending excessive amounts of bottom sediment.

There are several factors that can be altered to reduce turbidity. They are addressed in greater detail in Barnard (1978).

1. Cutter design.

2. Cutter removal (In some cases where the material will flow naturally (i.e., noncohesive materials), the effeciency of the dredging operation can be increased by removing the cutter altogether).

3. Suction (Sufficient suction to pick up all the material disturbed by the cutter will result in lower turbidity levels).

4. Cutter suction combination (New more efficient combination).

(d) Dredged Material Disposal Impacts

1. Introduction. Historically, disposal of dredged material has had significant adverse impacts on water quality, wetland, aquatic and terrestrial habitat. Each of these impacts is discussed separately. In addition, a section that discusses habitat development, which is a productive use of dredged material, is included.

2. Water Quality and Aquatic Habitat Impacts. They vary by type of disposal and are addressed in separate sections:

(a) Subaqueous Disposal of Dredged Material. The disposal of dredged material in open water can have the following impacts.

1. Alteration of water quality.

2. Release of sediment bound toxicants.

3. Covering of benthic organisms.

4. Creation of fluid mud.

5. Bottom topography effects.

An indepth review (Burks & Engler, 1978) of the published literature and results of the Dredged Material Research Program (DMRP) at WES indicate that open-water disposal of dredged material can have a temporary impact upon the receiving aqueous environment if the dredge sediments contain elevated levels of chlorinated pesticides, PCB's or ammonia. Harmful levels of heavy metals can be released from sediments at certain combinations of pH and oxidation-reduction potential but probably would not released by most typical dredging or disposal operations. Chlorinated hydrocarbon pesticides, PCB's, oil and grease compounds, heavy metals, and phosphates are rapidly absorbed by suspended particulate material in the water column that may resediment in quiescent areas.

Resedimentation of suspended particulates that have absorbed any of the above contaminants creates a potential for impact upon benthic organisms. After colonization occurs, detrialfeeding organisms may accumulate pesticides, PCB's, oil and grease compounds, and heavy metals and thus introduce these constituents into the biological food chain. These effects were reviewed and snythesized by Hirsch et al. (1978).

Depending upon the depth and nature of the sediments that cover the benthic organisms, there are several responses:

1. Death to some of the organisms.

2. Vertical migration of some of the organisms through the dredged material.

3. Recolonization of the dredged material from areas adjacent to the disposal site.

The magnitude of each individual response appears to be highly variable from site to site.

A literature review (Maurer et al., 1978) based on laboratory and limited field studies of other workers showed the following points:

1. Disinterment ability of organisms appears to be related to life habitat and body or shell morphology.

2. Exotic sediments (those in or on which the species in question does not normally live) are likely to have more severe effects when organisms are buried than sediments similar to those of the disposal site.

3. Smaller animals of a given type of organism are generally more susceptible to the effects of burial than are larger organisms.

4. There have been few attempts to determine the contribution of vertical migration to recovery after dredged material deposition.

In addition, Maurer et al, (1978) and Hirsch et al. (1978) postulate that environmental factors (e.g., the quality of the interstitial sedimentary waters) could be of great importance to vertical migration ability.

Studies at some sites where there was no vertical migration (Hirsch et al., 1978) showed trends toward reestablishment of the original community within several months of disturbance, and complete recovery was approached within one year. There was no predictable sequence of recolonization of disturbed areas. The study did not indicate the qualitative differences between existing bottom sediments and the deposited sediments in regard to organism impact. Disturbed areas such as shallower inshore waters, benthic regions near the head of a submarine canyon, and a harbor area were quicker to recolonize than normally undisturbed quiet water areas. The general recolonization pattern was dependent, in major part, upon the nature of the adjacent undisturbed community and its ability to provide a pool of replacement organisms capable of recolonizing the site by adult migration or larval recolonization.

Based upon his review of the literature, Wright (1978) concluded that open-water disposal appeared to have a negligible impact upon physical, chemical, and biological variables. However, the impacts observed were usually site-specific,

suggesting that the results from a limited number of sites cannot be universally applied or cited as being conclusive in all situations.

Overall, most impacts seemed to be relatively short-term. The conditions of the water column associated with disposal generally returned to ambient within minutes to hours. Chemical changes in the sediment persisted for days to weeks (where they occurred at all), while physical changes often lasted for several months. An exception concerned PCB's. However, PCB's are a rather unusual constituent of dredged sediment, and the fact that they were detectable long after disposal is not an indication that other contaminants behave in a similar manner (Wright, 1978).

In view of the limitation associated with the studies, the lack (i.e., apparent absence) of definitive impacts should not be construed to indicate that none existed. It may be a reflection of inadequate study design and great natural variability in the field, or a combination of these and other factors.

In addition, more concern over impacts <u>outside</u> of the designated disposal area rather than a concentration of effort <u>within</u> the disposal area would be helpful. In essence, a worst-case approach has been employed in that it was assumed that, if impacts were minimal within the disposal area, they would almost certainly be less outside of the disposal area. There is no firm reason to suspect that this was not the case, but it should be recognized that a lack of effects outside this disposal area is, in general, assumed and has not been exhaustively demonstrated (Wright, 1978).

One aspect not yet addressed is opportunities for habit enhancement. Aquatic

habitat development has the potential for being the largest application of habitat development from dredged material. The amount of waterway, river, and coastal bottom that is now natural aquatic habitat is enormous and much greater than for any other habitat type. Dredged material might be used to cover and eliminate contaminated sediments from the biologically active zone and allow the area to return to production of potential support populations. The production base of an area might be changed or enhanced through the selective application of dredged material as a means of changing sediment characteristics (i.e., mud bottom to sand), or providing a fresh supply of nutrient-rich material (i.e., as a thin supply of veneer), or as a controlled periodic disturbance to keep production of support populations high.

Aquatic environments incorporate a wide range of habitats (from submerged aquatic vegetation, to oyster and clam beds, to subtidal soft bottoms) that will react differently to the same treatment. In general, the aquatic habitats most susceptible to a disturbance and difficult to manage would be those that depend upon the presence of a particular species for their integrity, such as wild celery (Vallisneria), eelgrass (Zostera) beds or osyter reefs. The effective management of these types of aquatic habitats is strongly dependent upon understanding the natural history of the particular species and possibly establishing it as a target population.

Conversely, aquatic habitats not dependent upon any particular species, but rather the functioning of a group of species should be the least sensitive to disturbance or even localized extension. Most soft-bottom areas fit into

this category, being well adapted to a diversity of species that are able to perform similar functions, have life histories geared to taking advantage of opportunities, and utilize genetic selection to deal with all types of disturbance. All these characteristics make soft-bottom aquatic habitats most amenable to management.

In considering any type of aquatic habitat development, it would be important to analyze the history of the area chosen for development. The long-term or even short-term success of the habitat will depend greatly on past conditions, which will give a good indication of future conditions. For example, a seagrass bed would not be planted in a highly turbid area. The value of the area to be claimed or altered by the aquatic habitat also needs to be considered along with any management plans for the area. This would avoid conflict between the developed habitat's long-term resource value and management objectives for the area.

(b) Subaqueous Borrow Pits (Connor et al., 1979). Subaqueous borrow pits are irregularly shaped, shallow-sloped seafloor depressions caused by sand and gravel mining, typically for construction material and beach replenishment. In this alternative, dredged material would be transported to the spot over the pit, dropped through the water column into the pit, and covered with a layer of clean sand. It is anticipated that this would isolate the dredged material from the marine ecosystem.

However, there are some negative impacts. Biological impacts of dredged material deposition in borrow pits include the burial and general disruption of established communities in the borrow pit, and those related to short-term

water contamination and long-term sediment contamination. If a borrow pit is in an area of significantly different sediment grain size than the capping material (sand), benthic organisms would be affected and community structure altered. Initial construction of a borrow pit would also alter the benthic assemblage present and the significance of further disruption from filling the pit would be determined by the nature of the community at the time of filling.

In Mobile Bay, Alabama, pits were used by fish during colder months, but due to low dissolved oxygen levels in the summer, the dredged pits were not suitable as fish habitat (Broughton, 1977). In San Francisco Bay, borrow pits were pre-erred by striped bass and supported abundant seaweed and shellfish (Boroughton, 1977). Murawski (1969) reported that borrow pits were acceptable as fish habitats in New Jersey estuaries. These studies suggest that borrow pits might serve as artifically created habitat or congregation areas for fish and other free swimming marine organisms, at least seasonally. Filling of borrow pits would result in the removal of such artificial habitat.

(c) Beach Nourishment (Connor et al. 1979). The beach nourishment alternative involves the deposition of dredged sands onto beaches. The acceptability of a given sand for use in beach nourishment is dependent upon its grain size composition as well as that of the receiving beaches.

The direct biological impacts of beach nourishment are not severe and are of short duration assuming the use of compatible material. There would be little impact to beach organisms directly because they are generally mobile and

adapted to a constantly changing environment. There would be physical disruption and mechanical disturbance of benthic organisms caused by the addition of dredged material to a beach, particularly at the active discharge point. This may cause temporary reduction in the population density of intertidal benthic invertebrates in the discharge zone (United States Department of the Interior, 1974). The migration of animals from adjoining nonnourished beach areas is expected to quickly fill any ecological voids created by beach nourishment.

(d) Ocean Dumping (Conner et al., 1979). Disposal of dredged material results in several types of direct impacts to the local physical environment including:

1. Changes in submarine topography.

2. Alteration of existing sediment type.

3. Increases in concentrations of suspended particulates.

4. Sporadic deposition of sediment, resulting in a high but intermittent sedimentation rate.

These impacts result from the disposal of both contaminated and uncontaminated material. Direct physical impacts are generally observed only in the local area of the dump site because they are limited by the dispersion and fate of the disposed material.

3. Wetland Impacts. Disposal of material on wetlands usually results in more significant impacts to habitat due largely to the sensitivity of this ecosystem to change. The disposal of material may permanently cover and destroy wetland and intertidal mudflats, and will raise subaerial areas above their previous levels, with resultant changes in drainage, salt intrusion, water tables, etc. Wetlands and mudflat organisms and the birds

and wildlife which feed on them may be lost or displaced. New terrestrial habitats will be formed and, presumably, colonized by an assemblage of organisms appropriate to the situation. Finally, the area and topography of the wetland or intertidal shoreline will be modified and made more or less extensive, with resultant changes in the contribution to the system made by the communities associated with these types of areas.

As benthic wetland organisms are covered with dredged material, they will either migrate or succumb to smothering. Most will be unable to move with sufficient alacrity to avoid being smothered. The impact of this loss will be felt by waterfowl, which feed upon these organisms. The overall impact will be in proportion to the ratio of the affected area to the total of all such areas in the ecosystem.

The creation of new habitat may have positive effects on the ecosystem. In many cases, new bird nesting areas and/or wetlands may be created. This must, of course, be balanced against the destruction of feeding grounds in smothered wetland or tidal areas. Concerning tidal areas, it is possible that new habitat can be created which may not only maintain the existing tidal area but may enhance and increase this area. This relationship of land and tidal area might be made beneficial if dredged material were used to create many small islands bordered by shallow tidal muds rather than to fill shoreline areas with straight line tidal borders.

The COE Habitat Development Project studied the feasibility of constructing marshes with dredged material under a variety of actual field dredging and disposal operational conditions. The results of short-term observations, usually over two growing seasons following site development, are summarized by Clairain et al (1978), Lunz et al (1978), Allen et al (1978), and Cole (1978). These field studies concluded that, from the physical and vegetational viewpoints, it is possible to develop habitats that are structurally similar to natural habitats. By the end of the 2-year observation period, neither the structure nor the animal use patterns expected in response to that structure has equilibrated, and few conclusions concerning the function of the marsh were possible.

Once the evidence that marshes can be constructed using dredged material is accepted, the issue changes to

considering how marsh habitats can be manipulated in dredged ecosystems to best achieve management objectives. Marshes are known to benefit upland, semiaquatic, and aquatic animal populations. Marsh habitats provide great potential for animal-substrate interactions and make efficient use of energy under conditions of optimum association or interspersion with upland and aquatic habitats.

4. Terrestrial Habitat Impacts. The disposal of dredged material on land may permanently cover and destroy existing vegetation cover (COE, 1973). Breakage of plant stems and coverage of leaf surfaces such that photosynthesis may not occur essentially results in the destruction of such growth (COE, 1975). Although natural revegetation will occur with time, the extent and type of foliage may vary somewhat from existing foliage. The time required for natural revegetation is dependent upon the composition of the dredged material, frequency of disposal activities, and general fragility of the affected ecosystem.

If terrestrial animals use the vegetation along the shoreline as a habitat for feeding or for cover, then a component of the wildlife community will be adversely affected by the destruction of shoreline vegetation due to dredged material disposal. The vegetation which is covered will no longer provide a suitable habitat for terrestrial animals. This will result in a reduction in the numbers of terrestrial animals in the immediate area since these animals will move to adjacent areas with more suitable habitat. However, some of the animals will eventually be eliminated from the system due to competition for food and habitat (COE, 1975).

Deposition of dredged material along shorelines not only destroys shoreline vegetation, but it also alters the configuration of the shoreline. This is important, particularly for semi-aquatic species which move back and forth from the land to the water. Amphibians and reptiles are examples of species which typically behave in this manner. An area of shoreline may be very suitable for this migration to and from the water due to its physical characteristics and accessibility. However, the deposition of dredged material may change the shoreline configuration such that it is no longer suitable or accessible for semi-aquatic faunal migrations.

It may be noted that the significance of habitat alteration is proportional to the uniqueness of such habitat. The overriding issue is the ratio of the area affected compared with the total area of similar physical, chemical, and biological constitution.

Toxic effects of disposing dredged material can operate in two ways. One is through the biotoxicity of the dredged material to pioneering terrestrial vegetation which would otherwise colonize the newly created land area. The other is by leaching back into the wetlands ecosystem in freshwater runoff, along the tidal margins of the dredged material bank, or in intruding water beneath the dredged material. These effects will be in the form of acute toxicity, long-term low-level toxicity, or in the phenomenon of biological magnification.

There are opportunities for habitat creation/ enhancement. The most effective use of dredged material for upland habitat development appears to be in the construction of island or peninsular habitats where target animals can be provided a somewhat isolated breeding opportunity. Good breeding habitats for many target animals are barren and unproductive or too small and isolated to establish a permanent community capable of supporting resident predators. The maintenance costs for these areas may be absorbed in at least two ways: (a) physical permanence and the continued existence of the early, most productive successional stages can be achieved by intensive management for storm protection and vegetation control, or (b) these areas can be permitted to exist only temporarily, subject to natural erosive forces. The cost would then be computed for their initial construction and projected life without management.

Another island habitat type, for certain kinds of avian breeding, should be well developed with shrubs or trees. These islands would need to be larger (several hectares or more) and more permanent than the small barren islands often used by ground nesters, and the soil would need to be more fertile. Propagation of preferred plants may be advised if natural invasion is likely to be slow.

Other islands and peninsulas could be managed for waterfowl so that a dense cover of grasses, sedges, and herbs could be maintained. Island size may not be critical so long as the substrates remained permanently above water during the productive season and the islands were

isolated from effective predators. Meadows would be developed on relatively large islands or mainlands without diminishing their breeding value as long as a wetland nursery area existed nearby. Good waterfowl breeding habitats would be associated with partially inundated marshy or swampy habitats. The complex of upland and wetland could be designed by constructing islands or peninsular areas with protected lagoonlike embayments, and the arrangement and development of the area would be amenable to long-term, properly timed dredged material disposal operations.

Placement of dredged material for mainland habitat development appears less likely to be successful. In situations where a homogeneous plant cover exists, the use of dredged material to develop other successional stages with as much "edge" as possible would probably be the most valuable approach.

5. Habitat Development. It may be stated that habitat development is the consequence of every dredged material disposal operation not specifically designed to prevent the invasion and use of a disposal site by plants and/or animals. However, because of their intrinsic value to man, certain individual or groups of plants and animals may be identified by resource agencies as target species for management. Fundamental to this management, however, is a basic comprehension of how these target plants and animals interact with the physical, chemical, and other biological features of their environments.

Both target and support plant and/or animal populations must be identified. Animal species of direct interest to a habitat development/management plan are targets of that plan. They can be divided into three categories according to their commercial, recreational, or threatened or endangered status. Plant and animal species that are used by target animal populations for cover or food or other purposes are termed ecological support populations.

In most instances, a habitat development project will provide food (trophic support) or cover (physical or biological structure) critical to the completion of a target animal's life history. A given project could provide both.

It is widely believed by ecologists that the occurrence of a diversity of habitat types (increase in

spatial diversity) increases the resource value of the entire area to a greater number of species than any one of the individual habitats would (MacArthur 1960, Abele, 1974). The environmental planner could combine habitat types to produce a complex of greater value to the ecosystem than a monotonous expanse of similarly developed habitats. Multiple-use aspects of habitat development are also ehanced through the diversity of habitat types.

An approach to increasing habitat diversity would be to develop a series or succession of habitat types in the same place. This approach would use time as an integrator of habitat diversity as opposed to developing a variety of habitat types at once. For example, through successive disposal operations, a soft-bottom habitat could be first turned into a grass bed, then a wetland, than an island, and finally upland mainland. Careful management would be required for this approach, with constant evaluation of progress toward the final goal and the relative resource value of each step in the sequence.

RIVER TRAINING

River training consists of one or more dikes designed to develop and maintain the required channel dimensions and a particular channel alignment. It is essentially a finger-like projection extending outward from a bank into the river channel and effectively functions to lessen the river's width, direct the flow in the particular alignment and cause bottom scour to either deepen or maintain the selected navigation channel.

Dikes have been used most often in fluvial rivers, such as the Missouri and Mississippi, where sediment deposition encroaches on the main river channel and retards navigation. The positioning of a dike, however, changes the characteristic river flow patterns and, hence, alters the aquatic habitat in a commensurate manner. By acting to constrict the river channel, flow velocities in the remaining free-flowing main channel are increased, with a subsequent increase in bottom scour. This effects the obvious objective of a dike, i.e., to maintain or deepen a navigation channel.

The dike also creates a second type of aquatic environment, however, by acting as a breakwall and inhibiting current and flow on the downstream side of the dike. Here the river environment is characteristized by more lentic, pool-like waters with reduced velocities and increased sediment deposition, particularly along the interface between the faster flowing waters of the main channel and the backwater pool.

The following section presents the impacts to water quality and aquatic habitat resulting from the construction and operation of a dike.

(a) Construction Impacts

The only construction impacts are to aquatic habitat and water quality. The actual construction of a dike will destroy aquatic habitat by substrate coverage and disruption and will alter water quality through resuspension of settled materials and any bound chemicals (COE, 1975). The impacts, though, are very localized and temporary.

Dikes cover the river bottom and destroy the benthic community that inhabits the affected area. They usually create more surface area and a different substrate type for a new plant and animal community which becomes established after construction.

(b) Operation Impacts

1. Water Quality. As mentioned, dikes serve to constrict the main channel in order to maintain the navigation channel. The reduced width causes an increase in depth per unit of width and an increase in velocity, which results in an increase in the transport capacity of the channel waters (COE, 1976). Turbidity is greater in this free-flowing channel because of the increased capacity of the water to carry more suspended material. The increased turbidity results in a reduction of algae and their production of oxygen by photosynthesis. This can cause a detrimental impact up through the food chain. The increased transport capacity augments river bottom degradation by scouring, which resuspends and keeps in suspension

sediments including organic materials and other pollutants such as heavy metals and pesticides. These can result in a further reduction of water quality such as increasing BOD and COD and reducing dissolved oxygen concentrations.

When pile type dikes are constructed in a series, the flow velocity between dikes is reduced resulting in the deposition of suspended solids. This causes water quality to improve by reducing turbidity and suspended solids. Submerged dikes in a river tend to channelize flow. They increase the sedimentation rates on the bank side of the dike and increase bottom scour on the mid-channel size (COE, 1975).

2. Aquatic Habitat. In general, a dike may provide additional habitat, food, resting areas, shelter and refuge from predators. Dikes have been found to increase benthic diversity by providing artificial substrates but may decrease the diversity of all aquatic organisms by reducing the quantity and quality of habitat (Daley, 1977).

Within the lentic backwaters created by the dike, the reduction in flow velocities causes suspended materials to settle out. This sedimentation can alter the stream bottom and produce a mud-bottom habitat for aquatic organisms. The population of benthic invertebrates may change from one requiring strong currents and high dissolved oxygen concentrations to one preferring or tolerant of quiescent conditions and lower dissolved oxygen regimes. Increased stability of bottom sediments may accompany the reduction in flow velocity.

Lower velocities and less turbidity favor the growth of planktonic algae (COE, 1978) by permitting greater light penetration. Growth though, is primarily confined to the zone of light penetration. The oxygen produced by algae contributes to the dissolved oxygen concentrations in the water column.

The growth of planktonic algae and the suitable environmental conditions also benefits the growth of zooplankton populations. Increased planktonic organisms may subsequently cause an increase in the number of forage fish and the number of game fish.

An additional impact of dikes may be a reduction or elimination of fish populations specifically adapted

only to the main channel or its border habitats. Critically important to a species long-term survival, however, is the presence of suitable spawning grounds. Most catostomids (suckers), Acipenserids (sturgeons) and the paddlefish, for example, typically spawn in gravel bottoms in main channels. Transformation to lentic habitat will probably destroy these spawing grounds (COE, 1974). The impact of this elimination on these species is difficult to assess. Any change in benthic invertebrates, forage fish, aquatic and marsh vegetation and algae has the potential to affect the fish populations. This can be caused by a reduction in the quality of fish food or its character which can be deleterious to those species with specific food requirements.

Sedimentation, the increased amount of organic material present and the associated reduction in dissolved oxygen can also produce an unsuitable habitat for some species of fish. Floating debris tends to collect at piles and reduce the bank fishery and obstruct fish passage.

All these impacts can be mitigated to a degree by leaving openings or "notches" in dikes to permit or maintain slack water breeding areas.

3. Wetlands and Terrestrial Habitat. Heavy sedimentation behind the dikes may cause the formation of new wetland and/or terrestrial habitat.

LOCK OPERATION

The majority of the impacts associated with a lock and dam are with respect to the dam. It:

- Raises groundwater levels upstream.
- Lowers groundwater levels downstream.
- Causes the inundation of land.
- Effects aquatic habitat and water quality.
- Changes flood frequencies.
- Is a barrier to anadromous fish.

Once the presence of a dam is given, the effect of lock operation is quite small. The operation of a lock does cause hydraulic effects in its proximity. A venturi effect is generated on the downstream side by the water flowing through the lock and the velocity of water column, but sedimentation is very minor and is experienced only near the locks. Its effects on aquatic biota are considered insignificant (COE, 1978).

In addition, gate operation at low flows can regulate reaeration; e.g., for a given flow high discharge through a few gates aerates more efficiently than low discharge through many gates. Gate operations for aeration though, are subject to design, safety, and navigational constraints which can make them impractical.

No environmental ramifications resulting from operation of a lock system are cited in the professional literature (COE, 1979) or Corps Engineering Manual (COE, 1945). It is concluded that normal lockage routines are such that the exchange of water from the upper to lower pools compared to the overall volume of water present in the natural channel makes insignificant contributions to flow velocities and water elevations (COE, 1979). Therefore, there should be no significant impact on physical parameters downstream or on the related aquatic biota.

There are no wetland or terrestrial habitat impacts associated with lock operation.

It should be noted that there are indirect impacts, namely those associated with the incremental navigation activity permitted by the lock operation. These impacts are discussed under the major side heading: Actions to Increase Lock Capacity.

LOCK REHABILITATION

Major lock rehabilitation includes the following activities:

- Repair guidewalls.

- Repair lock chamber walls.
  - (a) Resurface vertical surfaces.
  - (b) Resurface tops of walls.
  - (c) Repair joints.
- Lock chamber stabilization.
- Rehabilitation of valves.
- Rehabilitation of valve machinery.
- Rehabilitation of gate.
- Rehabilitation of gate machinery.
- Rehabilitation of electrical system.

Depending upon the extent of the repairs to the guidewalls and the location of the valves needing rehabilitation a coffer dam may be required. All of the other activities can usually be performed by dewatering the lock.

If a coffer dam is not required there will be essentially no impact from the rehabilitation activities.

If a coffer dam is required there will be minor short-term impacts to aquatic habitat and water quality. The placement of the dam, dewatering and subsequent removal of the dam will destroy a small amount of aquatic habitat and cause some temporary increases in turbidity. There will be no long-term impacts.

ACTIONS TO INCREASE LOCK CAPACITY

(a) Construction Impacts

Modifications to existing locks or the addition of new lock chambers will have impacts similar to those of lock rehabilitation. These impacts have already been discussed.

(b) Operation Impacts

Actual physical lock operations themselves have negligible environmental impacts. The major impacts of lock operations, particularly higher levels of operations associated with increased capacity, are the impacts of the additional traffic which is accommodated. The discussion which follows is a generic discussion of the impacts of tow operations. It should be understood that these impacts would be generally more severe as a result of an action to increase lock capacity which actually resulted in more traffic being accommodated. Only the impacts on water quality, aquatic habitat, wetlands, and terrestrial habitat are addressed here.

1. Impacts to Water Quality and Aquatic Habitat. Four issues are discussed.

(a) Resuspension of Sediments. The passage of a boat or tow causes a displacement of water which may result in the temporary resuspension of sediments. The propeller wash can also be signficant in moving sediments (Ecological Consultants, 1978). Resuspension is dependent on such factors as the vessel size, speed, draft and direction of travel; the horsepower of the engine(s); the depth of channel; the characteristics of the channel bottom materials; and single versus multiple vessel passage (COE, 1976).

Larger boats and tows cause greater water turbulence and are closer to the channel bottom than smaller pleasure crafts. This results in greater resuspension of sediments. Faster moving vessels, those having greater drafts, and those which have engines of greater horsepower will have the same effect.

Upstream travelling will cause greater turbulence than that created by vessels travelling with the natural flow. Resuspension, therefore, will be greater.

The deeper a body of water is, the more distance there will be between the bottom of the vessel and the channel bottom, hence, the less resuspension there will be. The amount of turbulence at a given point is dependent on the distance the point is from the source of the turbulence. It tends to decrease as the distance from the source increases. The depth of the river is lowest during low-flow periods. The resuspension of sediments by a vessel will be greatest during these times. During high flow periods depths are greatest and resuspension of sediments can be minute or nonexistant.

Resuspension also depends on the size of the sediment particles and whether the bottom sustrate is soft and unconsolidated. The passage of boats and tows over a bottom substrate which is soft, unconsolidated, and composed of silt-size particles will cause much more resuspension of sediments than when they pass over a gravelly sand bottom.

After passage of the navigational vessel, turbulence will decrease and resettling will ensue. Particles settle at the site of disturbance or downstream of their original position because of river flow. They may settle within the main channel, along the banks, or within the backwaters depending on the swiftness of water and the size and weight of particles. Additional vessels will hinder settling and may cause resuspension of other particles.

The resuspension of sediments will reduce water quality. Turbidity and suspended solids concentration will increase. Turbulence may release such substances as pesticides, metals, methane, oil and grease, and nutrients from the bottom deposits and into the water column. Organic materials released into the

water column will decrease water quality by increasing biochemical oxygen demand and chemical oxygen demand and by decreasing dissolved oxygen concentrations. The effects of suspended sediment are discussed in Section IV.

The St. Louis District of the United States Army Corps of Engineers conducted a study in the Illinois Waterway during a period between medium and high river stages and found barge traffic to have very little effect on turbidity levels (COE, 1976).

The United States Army Waterways Experiment Station conducted a similar study in some areas on the Mississippi River and the Illinois Waterway during a period of normal pool conditions (Johnson, 1975). The study showed a significant temporary increase in suspended solids and turbidity after the passage of a tow. These increases were primarily observed in the main channel where depths range from 10 to 12 feet. No significant impacts existed where depths were 15 feet or greater. The period necessary for the level of turbidity and the concentration of suspended solids to return to ambient levels varied considerably. Recovery times were usually shorter than the three hour monitoring period following the passage of a tow. Complicating the conclusions is the fact that there were unexplainable wide variations in the turbidity and suspended solids during the absence of tow passage.

In the same study by Johnson (1975), dissolved oxygen concentrations showed no distinct variation correlated with tow passage. In most cases, tow traffic did not reduce dissolved oxygen (D.O.) concentrations in the main channel of the river. In some instances D.O. decreased slightly after passage of a tow.

Studies on the Illinois Waterway have actually shown steady increases in dissolved oxygen concentrations above initial levels which is attributed to the increase in turbulence by passing tows (COE, 1976). Starret (1971) reported temporary increases in turbidity of 200 Jackson Turbidity Units (JTU) in the Illinois Waterway immediately following the passage of a barge. An observable turbidity trail can extend for several miles behind a vessel (COE, 1976).

A study was conducted by the Water Quality Work Group of Great I to determine the effects of the first barge traffic of the season on the water quality of Lake Pepin in Minnesota (Great I, 1978). It showed that barge traffic causes resuspension of bottom sediments, even where water was 8.5 meters (28 feet) deep. After initial barge tow passage there was an increase in the concentrations of dissolved manganese, total manganese, total mercury, phenols, total phosphorus, suspended solids, total solids and total zinc; and a decrease in pH. The effects on water quality were only short-term, because they disappeared within 3 to 6 hours after the initial barge tow. This occurrence is attributed to settling and dispersion of resuspended bottom material.

(b) Wave Activity. Boats and tows produce waves which can accelerate erosion of shore areas including banks. This accounts for a portion of the increase in turbidity and the concentration of suspended solids experienced by a body of water because of navigational use. Most of the impact though, is restricted to shoreward areas. The contribution these waves make to natural erosion processes is a matter of dispute.

The heights of waves generated by boats and tows are dependent on boat speed (COE, 1975). As speed increases, the height of the generated waves increase. Therefore, a fast-moving, small pleasure craft will create higher waves than a slow-moving, large towboat. In wide channels, pools and lakes, waves created by wind may be more significant than those from boats.

(c) Waste Discharge. Commercial, industrial and recreational traffic on and along the nation's waterways presents a threat of pollution by waste discharges and bilge pumping. Federal and state regulations prohibit the purposeful discharge of waste.

The wastes of concern are such items as kitchen wastes and sewage (Ecological Consultants, 1978). Bilge pumping may contribute petroleum products and a multitude of other associated wastes from operation of the vessel and its cargo. Toxic compounds may be present. The discharge of wastes and bilge water is restricted by law. All vessels in operation today are equipped to store or treat wastes.

Another type of waste from a ship which may affect the environment is heat waste. Larger vessels have power plants for propulsion. The efficiency of such systems does not exceed 35%. Consequently, 65% of the energy from the fuel is disposed of as a waste of which much is waste heat.

This heat is either released directly into the atmosphere or into the surrounding waters depending upon the type of propulsion system. This may result in significant alteration of water temperatures (COE, 1972).

(d) Spills. Liquid and dry cargoes are carried on and along our nation's waterways by boats and tows. The release of these substances into the waterways can have an adverse impact on water quality and aquatic biota. Spills have occurred in the past and are certain to occur in the future.

Spillage of biological oxygen demanding compounds (such as grain or molasses) will usually not have a serious impact because they do not exert high oxygen demands over a short time period. Chemical oxygen demanding substances, such as some chemicals, may have a serious impact because they exert high oxygen demands over a short time period and thereby drastically reduce dissolved oxygen concentrations available to biota. Spills of toxic substances such as petroleum products, fertilizer (especially anhydrous ammonia), salt, and other similar chemicals will usually have the most serious impacts (Ecological Consultants, 1978).

Petroleum has naturally seeped and entered into the waters of the world in significant amounts for eons. Man, though, has increased the entry rate by several orders of magnitude (Robert R. Nathan Associates and Coastal Zone Resources Corp., 1975).

Accidental oil spills can be spectacular events and can attract the most public attention, though they only contribute about 10% to the total amount of oil released into the marine environment. The remaining 90% results from normal operation of oil tankers and other navigable vessels, off-shore oil drilling and pumping activities, refinery operations, and oil-waste material disposal.

The impact of oil on a particular situation depends on many factors such as: 1) the composition and amount of oil; 2) physiography, hydrography, and weather in the region of the spill; 3) biota characteristics and senstivity; 4) season of the year, and 5) previous exposure to oil. The composition and amount of petroleum plays an important role in its overall impact on the marine environment and biota. Physiography, hydrography and weather determines its spread, trajectory and dispersion. Different organisms have different responses to oil which vary from no effect to death of the organism. Sensitivity also varies according to the time of the year (spawning, migration, etc.). Certain life stages of an organism may have different sensitivities (COE, 1976).

The impact of oil on the biotic community of a region depends on the effect of oil on individual organisms and the changes that occur in species, populations, communities, and ecosystems as a result of effects on individuals. The least understood and most difficult aspects of the problem is the effect on the higher trophic levels in the food chain. Uncertainty in the spatial and temporal distribution of the biota and uncertainty about community and ecosystem dynamics prevent quantitative assessment of the ultimate impacts of spilled oil in any particular region (COE, 1976).

2. Impacts on Wetlands and Terrestrial Habitat.

(a) Noise Impacts. At present, little is known of the impact of noise on wildlife. Until such a time as additional data from field observations and associated laboratory research is available, impacts cannot be effectively and accurately predicted.

The noise of barge and tow boat operations could possibly have little or no effect on wildlife because wild animals may easily habituate to chronic increases in frequency of "barge noise". However, there are no known data to substantiate this assertion. New tow boat engines are required to have anti-noise devices and should, therefore, have less effect. However, it is possible that increased noise from navigation would be deleterious to species requiring more secluded breeding or resting areas. Noise may cause displacement of wildlife or produce other stresses on the ecosystem. This is particularly valid in and near wetland areas as these areas are often prime nesting, staging and breeding grounds for waterfowl and other avian species.

(b) Air Quality. It is doubtful the air pollution from navigational activities has a significant impact on the environment of the rivers (COE, 1976). Air pollution may pose a problem if the amount of pollutants contributed by navigation is coupled with that from increased industrialization along the shores associated with increased waterways activity.

It is also conceivable that prolonged navigational activities near wetland areas during sensitive avian breeding and staging periods could impact these activities resulting in their disruption.

(c) Impacts of Wave Action. Navigational activities within a river create waves which migrate to the shore where they may cause erosion of the banks and wetland areas. Erosion removes substrates and causes plant dislodgement, resulting in adverse impacts to aquatic, wetland, and terrestiral vegetation and wildlife habitat.

Wave action can also deter the growth and development of intolerant vegetation in wetlands and along banks. Shoreline vegetation which is destroyed by wave action could possibly cause an interruption of the natural food chain (COE, 1976) or cause the elimination of valuable wildlife habitat with resultant impacts to wildlife.

Shore-dwelling animals such as beaver and muskrat may be adversely impacted by wave wash. Their young would be most vulnerable in their bank dens. Erosion from wave action may also physically destroy lodges and dens. Herpetofauna, dependent on shorelines for breeding may also be adversely affected. As noted earlier high speed recreational craft create larger waves than slow commercial vessels and tows.

(d) Cargo Spillage. Liquid and dry cargoes are transported on waterways by self-propelled vessels boats and barge tows. The release on these substances into the waterways may have a detrimental effect on wetland vegetation and wildlife.

For example, spilled cargo may affect terrestiral animals. Wildlife associated with the river such as muskrat, beaver and waterfowl can be directly affected by the released substances. Other terrestrial animals may ingest polluted waters or consume aquatic or other terrestrial, plants and animals affected by the spilled substances causing impact at higher trophic levels. The elimination of vegetation may also adversely effect the population of a herbivore and the elimination of a prey may likewise affect the predator population.

(e) Waste Discharge. Wetlands and Terrestrial Habitats are also threatened by

waste discharges similar to those described for Water Quality and Aquatic Impact.

MINOR AND NON-STRUCTURAL ACTIONS

Certain actions may be performed to either increase lock capacity or improve safety. They include actions with insignificant negative environmental impacts including:

1. Radar transponders at bridges.

2. Radar reflectors at bridges.

3. Establishment of enhanced vessel traffic services at locks and ports.

4. Placement of aids to navigation.

5. N-up and N-down lock operating procedures.

6. Elimination of conflicts caused by recreational traffic at locks by processing commercial and recreational traffic together or by publishing limited times for recreational lockages.

7. Use of helper boats at locks.

8. Ready-to-serve lock operating policy.

They also include minor construction/removal activities which could cause minor short-term increases in turbidity and/or disruption to aquatic habatit. They include:

1. Removal of abandoned mooring cells, bridges, piling and other obstructions.

2. Installation of mooring cells and guidelines at locks.

3. Bridge fenders.

It should be noted that activities that improve safety have a long-term positive environmental impact by reducing the possibility of cargo spills.

CHANNEL DEEPENING/ WIDENING

(a) Clearing and Snagging Activities

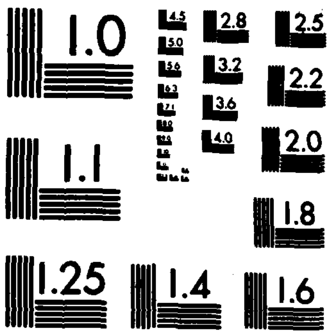
Clearing and snagging operations remove obstructions in the river. Though they benefit navigation, adverse and beneficial impacts to water quality and aquatic biota may ensue.

1. Water Quality. Clearing and snagging activities remove substances from the river which decay and otherwise increase the biochemical oxygen demand (BOD), chemical oxygen demand (COD), or metals concentrations. Snags cause restricted flow during the low flow season and create stagnation problems. Their removal eliminates the impacts to flows and water quality (COE, 1975). Although their removal from the river benefits water quality, the physical removal cause the resuspension of sediments. The amounts of materials and chemicals resuspended usually are not sufficient the cause significant and long-term changes in water quality (COE, 1975). Suspended solids concentrations may increase but sedimentation often occurs shortly after resuspension further downstream. Resuspension of oxygen demanding substances can cause a reduction in dissolved oxygen concentration but because of sedimentation, the small quantities resuspended, and reaeration, the impact is not significant. The impacts associated with resuspension of other materials, such metals, are also insignificant.

2. Aquatic Habitat. Clearing and snagging operations affect aquatic biota by removing debris which serve as suitable habitat. It may afford a substrate for benthic and periphytic organisms, a source of food for organisms which feed on detritus, a population of organisms on which other organisms feed or produce eddy currents and pockets of almost stationary water which provides flow variation and may diversify aquatic habitat. Sediment carried by the river tends to settle in these areas producing a bottom habitat which may be different than that

AD-A127 294 EVALUATION OF ALTERNATIVE FUTURE STRATEGIES FOR ACTION 4/4
(U) KEARNEY (A T) INC CHICAGO ILL J EGAN ET AL. SEP 81
DACW72-79-C-0003

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

in most other areas. Some aquatic organisms prefer these currents, pockets of almost stationary water, and/or bottom habitat and may only be found in the river areas having these characteristics.

3. Terrestrial Habitat. Land disposal of the material removed from the channel may cause some minor impacts.

(b) Rock Removal

1. Water Quality. The blasting of rocks in the main channel will cause the temporary resuspension of sediments. The amounts of materials and chemicals resuspended usually are not sufficient to cause significant and long-term changes in water quality. Suspended solids concentrations may initially increase but downstream sedimentation usually occurs shortly after resuspension. Resuspension of oxygen demanding substances can cause a reduction in dissolved oxygen concentrations but because of sedimentation the small quantitiies resuspended and reaeration, the impact is not significant. The impacts associated with resuspension of other materials such as metals are also insignificant.

2. Aquatic Habitat. The blasting will have a limited impact on fish (COE, 1975). It can be expected to kill some fish in the immediate area of explosion. Fish, though, normally do not inhabit the deeper, main channel where blasting is necessary because there is a limited amount of food available in comparison to that in the nearshore areas. In addition, research by the United States Fish and Wildlife Service has shown that minimal destruction of fish occurs in areas further than 50 feet from a blast of this type.

Plankton and benthic organisms are relatively rare in the deeper, main channel where blasting occurs and, therefore, blasting will have little impact upon the aquatic community in general (COE, 1975).

Normally, when an obstruction such as a rock exists in a stream it produces eddy current, areas of almost stationary water, scouring downstream, and shoaling even further downstream. This diversifies habitat and may benefit some aquatic organisms while being detrimental to others. The removal of these rocks will eliminate the habitat they produce.

(c) Dredging

Channel deepening or widening may result in both new project dredging and additional maintenance dredging throughout the life of the project. The impacts of dredging and dredged material disposal have been discussed.

PORT DEEPENING

The primary activities associated with port deepening are dredging and/or rock removal. Dredging and dredged material disposal have been discussed. Rock removal has also been discussed.

Another impact which would occur at some ports (e.g., Baltimore) is the increase in salinity levels as a result of channel deepening. This deepening potentially encroaches upon fresh water aquifers.

SUMMARY OF GENERIC IMPACTS

Of the actions addressed, the one with by far the greatest impact is dredging and dredged material disposal. This includes both new work and maintenance dredging. Thus, the activities with the greatest controversy will include:

- Maintenance dredging.
- Channel deepening.
- Port deepening.

In the past, dredged material was termed and thought of as "spoil". Thus, it was disposed of in an inexpensive fashion, which was not always the soundest from an environmental perspective. However, the Corps has performed much research into productive uses of dredged material. With proper planning, the negative impacts of dredged material disposal can either be mitigated/minimized or turned into positive impacts through productive uses such as habitat enchancement. Obviously, those areas with polluted sediments (most harbor areas) will have the greatest problems. The only other activity of significant concern

is the actual movement of tows in the rivers. While the scientific community is divided on the magnitude of these impacts as compared to natural processes (e.g. floods, wind, etc.), property owners along many rivers (e.g. the Ohio River) have become very vocal. Thus, activities that would increase waterway traffic (e.g. increasing lock capacity) may be controversial.

All other actions have quite minimal impacts.

BIBLIOGRAPHY

Abele, L. G. 1974. Species diversity of decapod crustaceans in marine habitats. Ecology. 55:156-161.

Allen, H. H., E. J. Clairain, Jr., R. J. Diaz, A. W. Ford, L. J. Hunt, and B.R. Wells. 1978. Habitat development field investigations. Bolivar Peninsula marsh and upland habitat Galveston Bay, Texas; Summary report. Technical Report D-78-15. U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi.

Arner, D. H., H. R. Robinette, J. E. Frasier, and M. Gray, 1975. Effects of Channel Modification on the Luxapalila River. In, Symposium on stream channel modification, R.V. Corning, R.F. Raleigh, G.D. Schuster, Sr., and A. Wood (eds.) Harrisburg, Virginia.

Barnard, W. D. (1978) Prediction and Control of Dredged Material Dispersion Around Dredging and Open-Water Pipeline Disposal Operations. Corps of Engineers Waterways Experiment Station Tech. Report DS-78-13.

Bayless, J. and W. B. Smith, 1964. The Effects of Channelization Upon the Fish Population of Lotic Waters in Eastern North Carolina. Proc. Ann. Conf. S.E. Assoc. Game and Fish Comm.

Burks, S.A. & R.M. Engler (1978) Water Quality Impacts of Aquatic Dredged Material Disposal (Laboratory Investigations) Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi Tech. Report DS-78-4.

Clairain, E. J., Jr., R. A. Cole, R. J. Diaz, A. W. Ford, R. T. Huffman, L. J. Hunt, and B. R. Wells. 1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon; Summary report. Technical Report D-77-38. U.S. Army Engineer Waterways Experiment Station, C.E, Vicksburg, Mississippi

Cole, R. A. 1978. Habitat development field investigations, Buttermile Sound Marsh Development Site, Atlantic Intracoastal Waterway, Geogia; Summary report. Technical Report D-78-26. U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi

Congdon, J. C., 1971. Fish populations of channelized and unchannelized sections of the Chariton River, Missouri. Stream channelization - A symposium. In E. Shenneberger and J.L. Funk (eds.). North Central Div., American Fish. Soc. Special Pub. No. 2.

Conner, W. G. et al. (1979) Disposal of Dredged Material Within the New York District Vol. 1 Present Practices and Candidate Alternatives. MTR-7808.

Corps of Engineers Office, Chief of Engineers, Department of the Army, CE, "Hydraulic Design - Navigation Locks," Engineers Manual EM 1102-21604, April 1945, Washington, D.C. 20315.

Corps of Engineers, Institute of Water Resources, 1972. U.S. Deepwater Port Study - The Environmental and Ecological Aspects of Deepwater Ports.

Corps of Engineers (1972) Specifications for Dam and Appurtenances, Phase No. 1, Bloomington Lake. Baltimore District Baltimore, Maryland, Sections 2-13, November 9, 1972.

Corps of Engineers, Water Quality Criteria 1972, prepared by the National Academy of Sciences, National Academy of Engineering Committee on Water Quality, for the EPA, Washington, D.C., July 22, 1972.

Corps of Engineers, Analyzing the Environmental Impacts of Water Projects, U.S. Army Engineer Institute for Water Resources, NTIS, U.S. Department of Commerce, Virginia, 1973.

Corps of Engineers, 1974. Draft Environmental Statement - Operation and Maintenance of a Nine-Foot Channel in the Illinois Waterway.

Corps of Engineers, Portland District, 1974. Environmental Impact Statement - Matilla - The Dallas, Construct, Operation, Management.

Corps of Engineers, St. Louis District, 1974. Final Environmental Statement - Locks and Dam No. 26 (Replacement), Upper Mississippi River Basin.

Corps of Engineers, Portland District, 1975. Columbia and Lower Willamette River Environmental Statement.

Corps of Engineers, St. Louis District, 1975. Draft Environmental Statement - Vol II Physical and Cultural Appendices, Locks and Dam No. 26 (Replacement), Upper Mississippi River Basin.

Corps of Engineers, 1975. Environmental Assessment of the Mississippi River and Tributaries Project. Prepared by Rychman, Edgerley, Tomlinson and Associates, Inc.

Corps of Engineers (1975). Final Composite Environmental Statement Maintenance Dredging Existing Navigation Projects San Francisco Bay Region, California. San Francisco District.

Corps of Engineers, Huntington District, 1975. Final Environmental Impact Statement - Kanawha River Navigation System - Fayette, Kanawha, Putnam & Mason Counties, West Virginia.

Corps of Engineers, Pittsburgh District, 1975. Final Environmental Statement on the Operation and Maintenance of the Navigation System - Monongahela River.

Corps of Engineers, Allegheny River, Pennsylvania, Final Environmental Statement, Operation and Maintenance of the Navigation System, Pittsburgh District, October 1975.

Corps of Engineers, Chicago District, 1975. Final Environmental Statement - Operation and Maintenance of a Nine-Foot Channel in the Illinois Waterway.

Corps of Engineers, Nashville District, 1975. Open Channel Maintenance - Tennessee River and Tributaries.

Corps of Engineers, Nashville District, 1975. Operation, Maintenance and Management of Water Resource Development Projects, Cumberland River.

Corps of Engineers, Lower Mississippi Valley Division and Galveston, New Orleans, and Mobile Districts; 1975. Report on Gulf Coast Deep Water Port Facilities - Texas, Louisiana, Mississippi, Alabama and Florida. Appendix F - Environmental Assessment, Vol. IV - Environmental Impact.

Corps of Engineers, (1976) Dredge Disposal Study, San Francisco Bay and Estuary. Appendix C. San Francisco District.

Corps of Engineers, 1976. Final Environmental Impact Statement, McNary. Walla Walla, Washington.

Corps of Engineers, 1976. Final Environmental Impact Statement - Mississippi River Between the Ohio and Missouri Rivers - Regulating Works.

Corps of Engineers, 1976. Revised Draft and Supplement Environmental Statement, Volume 1, Locks and Dam No. 26 (Replacement) Upper Mississippi River Basin Mississippi River-Alton, Illinois, Missouri and Illinois, St. Louis District.

Corps of Engineers, 1977. Fish and Wildlife Habitat Changes Resulting From Construction of a Nine-Foot Navigation Channel in the Illinois Waterway.

Corps of Engineers Office, Chief of Engineers, Department of the Army, CE, "Engineering and Design - Nitrogen Supersaturation," Engineering Technical Letter No. 1110-2-239, 15 September 1978, Washington, D.C. 20315.

Corps of Engineers, Ohio River Division, Draft Environmental Impact Statement 1978. Ohio River Navigation Project, Operation and Maintenance.

Corps of Engineers, Rock Island District, 1978. Environmental & Social Considerations of Mississippi River, Year-Round Navigation Program.

Corps of Engineers, 1979. Identify, Document and Evaluate the Effect of Waterway Structure Operational Procedures on Environmental Quality, Draft.

Corps of Engineers, North Central Division. Phase I Report, Mississippi River Year-Round Navigation.

Daley, Richard H., 1977. Biological Issues and Concerns on the Mississippi River Mainstream from Cairo, Illinois to Saverton, Missouri. Prepared for the Upper Mississippi River Basin Commission.

deBree, S. E. M. (1977) The Loading of Hopper Dredgers. Ports and Dredging and Oil Report, No. 92 pp. 4-8.

Duvel, W. A. Jr., R. D. Volkmar, W. L. Specht and F. W. Johnson, 1976. Environmental Impact of Steam Channelization Water Resources Bulletin Vol. 12, No. 14, 799-812.

Ecological Consultants, Inc., 1978. Evaluation of the Navigation Effects on the Biological Components of the Upper Missippi River Aquatic Ecosystem. Preliminary Draft prepared for the Upper Mississippi River Basin Commission.

Elser, A. A., 1968. Fish Populations in Relation to Major Habitat Zones and Channel Alteration. Trans. Amer. Fish Soc. 97 (4):389-397.

Etneir, D. A., 1972. The Effect of Annual Rechanneling on a Stream Fish Population. Trans. Amer. Fish. Soc. 101(2):372-375.

Great I Water Quality Work Group (1978a). A Pilot Study on Effects of Hydraulic Dredging and Disposal on Water Quality of the Upper Mississippi River.

Great I (1978b). Effects of Clamshell (Mechanical) Dredging and Disposal on Water Quality of the Upper Mississippi River Water Quality Work Group. St. Paul District, Corps of Engineers.

Griswold, Edwards, Woods and Weber, 1978. Some effects of stream channelization on fish populations, macroinvertebrates, and fishing in Ohio and Indiana. U.S. Fish and Wildlife Service, FWS/OBS-77/46.

Gustafson, J. R. (1972) Beneficial Effects of Dredging Turbidity. World Dredging and Marine Construction 8 (13) 44-45, 47-48, 50-52, 72.

Hanson, D. R., 1971. Stream Channelization Effects on Fishes and Bottom Fauna in the Little Sioux River, Iowa, Stream Channelization - A Symposium, In E. Shenneberger and J.L. Funk (eds.). North Central Div. Amer. Fish. Soc. Special Publ. No. 2.

Henegar, D. L. and K. W. Harmon, 1973. A review of references to channelization and its environmental impact In: Stream channelization - A symposium, E. Shenneberger and J.L. Funk, Editors. North Central Division American Fish. Society, Spec. Publ. No. 2.

Herbich, J. B. (1975) Coastal and Deep Ocean Dredging. Gulf Pub. Company, Houston, Texas. 622pp.

Hirsh, N. D., L. H. DiSalvo, R. Peddicord (1978) Effects of Dredging and Disposal on Aquatic Organisms. Corps of Engineers Waterways Experiment Station. Tech. Report DS-78-5.

Huston, J. W. (1970) Hydraulic Dredging, Theoretical & Applied. Cornell Maritime Press, Cambridge, Maryland.

Huston, J. W. and W. C. Huston (1976). Techniques for Reducing Turbidity Associated With President Dredging Procedures and Operations. Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. Contract Report D-76-4.

Hynes, H. B. N., 1974. The biology of polluted waters. University of Toronto Press.

Irizarry, R. A., 1969. The effects of stream alteration in Idaho. Idaho Fish and Game Dept., Boise. Job Completion Rep., Project F55-R-2.

Johnson, J. H. 1975. Effects of Tow Traffic on the Resuspension of Sediments and Dissolved Oxygen Concentrations in the Illinois and Upper Mississippi Rivers Under Normal Pool Conditions. (Preliminary Working Draft). Corps of Engineers Waterways Experiment Station.

Lund, J. A., 1976. Evaluation of stream channelization and mitigation on the fishery resources of the St. Regis River, Montana. Office of Biological Services, US Fish and Wildlife Service, Washington, D.C., Publication No. FWS/OBS-76/06.

Lunz, J. D., T. Zeigler, R. T. Huffman, B. R. Wells, R. J. Diaz, E.J. Clairain, Jr., and L. J. Hunt. 1978. Habitat development field investigations, Windmill Point Marsh Development Site, James River, Virginia; Summary report. Technical Report D-77-23. U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi.

MacArthur, R. 1960. On the relative abundance of species. American Natural. 94:25-36.

Mauer, D. L. et al. (1978). Vertical Migration of Benthos in Simulated Dredged Material Overburdens, Vol. I: Marine Benthos. Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi Tech. Report D-78-35.

Morris, L. A., R. N. Langemeier, T. R. Russel; and A. Witt, 1968. Effects of main stem impoundments and channelization upon the liminology of the Missouri River, Nebraska. Trans. Amer. Fish. Soc. 97 (4):380-388.

Robert R. Nathan Associates and Coastal Zone Resources Corp., 1975. The Coastal Plains Deepwater Terminal Study, Volume 1. Prepared for the Coastal Plains Regional Commission.

Peddicord, R. K. and V. A. McFarland (1978). Effects of Suspended Dredged Material on Aquatic Animals. Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi Tech. Report D-78-29.

Prellwitz, D. M., 1976. Effects of stream channelization on terrestrial wildlife and their habitats in the Buena Vista Marsh, Wisconsin. Prepared for U.S. Fish and Wildlife Service, FWS/OBS - 76/25.

Purkett, C. A., Jr., 1957. Growth of the fishes in the Salt River, Missouri. Trans. Amer. Fish. Soc. 87:116-131.

Schneberger, E. and J. L. Funk, ed., 1971. Stream channelization: A Symposium. N.C. Div., Am. Fish. Soc., Spec. Publ. 2.

Slotta, L. S. et al. (1964). An Examination of Some Physical and Biological Impacts of Dredging in Estuaries. PV240-742.

Starrett, W. C., 1972. Man and the Illinois River. In: River Ecology and Man. R. T. Oglesbey, C. A. Carlson and J. A. McCann (EOS.), Acad. Press.

Stern, E. M. & W. B. Stickle (1978). Effects of Turbidity & Suspended Material in Aquatic Environments - Literature Review. Corps of Engineers Waterways Experiment Station. Vicksburg, Mississippi Tech. Report D-78-21.

Sustar, J. F., T. H. Wakeman, R. M. Ecker (1976). Sediment-Water Interaction During Dredging Operation. In: Proc. of Specialty Conf. on Dredging and its Environmental Effects. Mobile, Al. (Jan. 26-28, 1976). Publ by ASCE. 1040 + pp.

Tarplee, W. H., Jr., D. E. Louder, and A. J. Weber, 1971. Evaluation of the effects of channelization on fish populations in North Carolina's coast plain streams. N.C. Wildl. Resource Comm., Raleigh.

Thorn, M. F. C. (1975). Loading and Consolidation of Dredged Silt in a Trailing Suction Hopper Dredger. First International Symposium on Dredging Technology. pp. B1-1 to B1-14.

Trautman, M. B. and D. K. Gartman, 1974. Re-evaluation of the effects of manmade modifications on Gordon Creek between 1887 and 1973 and especially as regards its fish fauna. Ohio J. Sci. 74(3).

U.S. Congress, House of Representatives, Subcommittee on Conservation and Natural Resources, Committee on Government Operations; 1971. Hearings on stream channelization. 92 Congress, 1st Session.

Wright, T. D. (1978). Aquatic Dredged Material Disposal Impacts. Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi Tech Report DS-78-1.

Yagi, T. et al. (1975). Effect of Operating Conditions of Hydraulic Dredges on Dredging Capacity and Turbidity. (Translation from Japanese) No. 228, September 1975, Port and Harbor Research Institute, Ministry of Transport, Yokosuka, Japan.

Zimmer, D. W. and R. W. Bachman, 1978. Channelization and invertebrate drift in some Iowa streams. AWRA paper No. 77111 of the Water Resources Bulletin Vol. 14, No. 4.

APPENDIX D

LINEHAUL COST EVALUATION METHODOLOGY FOR CHANNEL DEEPENING

PURPOSE OF THIS APPENDIX

The purpose of this appendix is to document the process by which the effects of channel deepening on line-haul costs on the affected inland shallow draft waterways were evaluated for Strategy IV. The subject is given special treatment here due to the unexpected findings of the evaluation process. Also, a variety of sources were consulted that require documentation. The remainder of this appendix is orgainized into the following topics:

- NEED FOR SPECIAL ANALYSIS
- APPROACH TO THE PROBLEM
- ADJUSTMENTS TO HORSEPOWER/TONNAGE RATIOS
- FINAL DATA CHANGES
- CONCLUSIONS
- SOURCES

NEED FOR SPECIAL ANALYSIS

Since one strategy (Strategy IV) utilized channel deepening as a major means of improving linehaul cost, it was necessary to develop a mechanism for incorporating the effects of deepening into the evaluation process[1]. The strategy was formulated based on the premise that deepening had traditionally provided major gains in linehaul cost in the past and available information suggested that such gains could be continued by still more channel deepening.

---

[1]For a discussion of the relationship of channel depth and other characteristics to linehaul cost see Section IV of the K2 Report.

There were two major requirements for evaluating the effects of deepening on linehaul cost. These were adjustments to the data used for calculating linehaul cost (presented in Appendix D of the Element K2 Report -- Evaluation of the Present Navigation System) and a means for taking into account the fact that only some segments were to be deepened, not the entire system.

Finally, in addition to evaluating the effects of deepening on linehaul costs it was also necessary to incorporate the effects of channel deepening in calculating lock capacities in subsequent years.

APPROACH TO THE PROBLEM

The approach to this analysis was the same as that used for all other aspects of the Integration Work. That is, available (preferably published) souces and data were to be relied upon with a minimum of original work undertaken. Two sources were initially identified and reviewed. Additional information and advice was sought from a major manufacturer of floating equipment. Preliminary analyses were carried out and presented at the public meetings in November of 1980. As a result of those meetings some additional information was obtained. Also, a third published source was reviewed. The review of these additional two sources resulted in further modifications to the analysis.[2]

ADJUSTMENTS TO HORSEPOWER/ TONNAGE RATIOS

The first source reviewed (the Corps North Central Division 12 foot channel study) indicated that cost reductions would be almost proportional to the increased ladings made possible by deepening. This would imply that little or no change would be required in the horsepower used to propel these tows over the horsepower required for existing depths. Thus large gains in linehaul cost could be achieved by spreading the cost of the towboat and fuel over a larger tonnage.

---

[2]For complete citations of all published sources utilized, see the last topic in this appendix.

The Element K1 report (Engineering Analysis of Waterways Systems) was also consulted on this issue. This report indicates that the ratio between horsepower required and tonnage is constant. If true this would mean that savings from deepening would be quite small since two major cost items (power and barge costs) would increase directly with ladings.

Faced with this contradiction between two extreme positions, neither of which appeared fully defensible, additional information was required. A major manufacturer of inland marine equipment (noted for innovation and advanced design capabilities) was consulted. The representative of this firm indicated that he was not sure what additional horsepower would be required (assuming the same clearances under the tows) to move more deeply laden tows. However, it seemed reasonable to him that additional power would be required and he cited a figure consistent with the Element K1 approach. Consequently, the linehaul cost changes were computed on this basis and presented in the public meetings in November 1980.[3] The problem with the analysis was also discussed at those meetings and additional input was solicited.

As a result of the meetings in November 1980, the commander of the 2nd District of the U.S. Coast Guard provided data in the form of a set of curves relating underkeel clearances, horsepower requirements, tow configurations, and drafts. These curves were based on tank tests with models conducted for the Ohio River Division of the Corps of Engineers by the University of of Michigan in 1960. In general these curves showed that more power was requried for deeper drafts but that power requirements did not increase in direct proportion to ladings.

---

[3]As it turned out, the results presented at those meetings did not reflect any change in linehaul operations whatsoever due to an error in the computer program which was discovered during the preparation of this report. The results presented at those meetings were based solely on reductions in delays at locks. The error has been corrected and the results presented in this report incorporate all the improvements analyzed.

A third published source, a recent study by the Maritime Administration of the U.S. Department of Commerce was also reviewed at this time. This study analyzed the relationship of depth and speed (and concomitant power requirements). This study relied upon model tests reported in 1934 by an Otto Schilling, who performed some analysis for the German Admiralty. The review of these last two sources yielded the following conclusions:

1. Operating efficiencies improve rapidly from extremely shallow drafts (3 feet to 5 feet) to the drafts most common today (9 feet).[4]

2. Operating efficiecies continue to improve at greater depths, but less rapidly than for shallower depths.

3. Actual drafts per se are not as important as the depths under the hull. Bottom and side clearances are important because of the restrictive effects of these clearances on the flow of water around the hull.

Since the same clearance under tows as is available in the present system was explicitely assumed to be provided with the deepening actions in Strategy IV it was possible to focus on the family of curves derived from the University of Michigan tests to estimate the adjustments necessary to the base linehaul costing data. The adjustment factors applied to the horsepower per ton ratios were .98 for a 10 feet channel and .93 for a 12 feet channel. This adjustment compled with more advantageous barge costs per ton yields an improvement of about 15 percent for a 12 feet channel without locks. This is considerably less than the improvement indicated in the Corps 12 feet channel study, but is a significant improvement nonetheless.

FINAL FOR DATA CHANGES

Improvement in linehaul cost was projected for several segments, included segments not deepened beyond present system depths, based upon traffic interaction. The changes in linehaul cost variables are summarized in Table D-1.

---

[4]This conslusion is also supportedby the Element K1 Report (Engineering Analysis of Waterways Systems).

The change in ladings in Table D-1 is applied to the ladings shown in Appendix D to the Element K2 Report (Evaluation of the Present Navigation System). The same percentage increases were also applied to ladings at affected locks. The changes in horsepower were applied to the corresponding fuel consumption data in Appendix D of the Element K2 Report

CONCLUSIONS

The apparent uncertainty about the effects of deepening inland river channels and the associated changes in operations probably stems from the fact that the major existing channels and dominant depth of 9 feet have been in place since before World War II. Because there have been no major changes since then operations and equipment have been tailored to that environment and there is little experience with greater depths. Consequently there is little factual basis on which to make linehaul cost projections. Clearly any program to deepen channels will have to explore these issues more thoroughly, borrowing perhaps from the operating experience on the New York State Barge Canal and the Columbia-Snake system, both of which have depths greater than 9 feet.

SOURCES

The following sources were consulted during this analysis:

1. U.S. Army Corps of Engineers, National Waterways Study, Analysis of Waterways System Navigation Capability, Review Draft (April 1980).

2. U.S. Army Corps of Engineers, North Central Division, Mississippi River - Illinois Waterway 12 Foot Channel Study Phase I Report, Appendix B (September 1973).

3. U.S. Department of Transportation, Second Coast Guard District, Letter dated November 28, 1980.

4. U.S. Department of Commerce, Maritime Administration, Least Energy Operation of River Shipping, Vol. II: Detailed Analyses and Appendices (January 1980).

TABLE D-1

SUMMARY OF LINEHAUL DATA ADJUSTMENTS FOR DEEPENING ACTIONS STRATEGY IV

NWS Region	NWS Segment	Changes in Depth Under Strategy IV (feet)	Change in Ladings (%) 1/	Traffic Weight (%) 2/	Horsepower Adjustment (%)
1. Upper Mississippi	1. Upper Mississippi	1	12.5	48 3/	98
2. Lower Upper Mississippi	2. Lower Upper Mississippi	0 4/	37.5	61 5/	93
3. Lower Mississippi	3. Middle Mississippi	3	37.5	61 5/	93
	4. Lower Middle Mississippi	0 6/	37.5	100	93
	5. Upper Lower Mississippi	0 6/	37.5	100	93
	6. Lower Mississippi-Old River to Baton Rouge	0	37.5	100	93
4. Baton Rouge to Gulf	7. Mississippi River, Baton Rouge to New Orleans	0	37.5	100	93
	8. Mississippi River, New Orleans to Gulf	0	37.5	100	93
	26. Old and Atchafalya River	0	12.5 7/	100	0
	27. Baton Rouge - Morgan City Bypass	0	12.5 7/	100	0
5. Illinois Waterway	9. Illinois Waterway	3	37.5	100	93

TABLE D-1 (cont'd)

SUMMARY OF LINEHAUL DATA ADJUSTMENTS FOR STRATEGY IV

NWS Region	NWS Segment	Changes in Depth Under Strategy IV (feet)	Change in Ladings (%) 1/	Traffic Weight (%) 2/	Horsepower Adjustment (%)
7. Ohio River	11. Upper Ohio River	3	37.5	60 8/	93
	12. Middle Ohio River	3	37.5	60 8/	93
	13. Lower Ohio River - Three	3	37.5	60 8/	93
	14. Lower Ohio River - Two	3	37.5	60 8/	93
	15. Lower Ohio River - One	3	37.5	60 8/	93

NOTES: 1/ These adjustments were also applied to all affected locks.

2/ This weight is applied to allow for significant intraction with channels not deepened. This was also applied to affected locks.

3/ Based on 48 percent of traffic moving only on deepened portion of this segment.

4/ Already capable of accommodating 12' draft tows.

5/ Based on mix of Illinois River and Upper Mississippi traffic.

6/ Projected to be capable of accommodating 12' draft tows as part of the "present system."

7/ Based on present depths greater than 9' but less than 12'.

8/ Based on 40 percent of main stem tonnage interacting with other segments not deepened.

APPENDIX E

ENVIRONMENTAL SENSITIVITY ANALYSIS

BACKGROUND AND PURPOSE OF APPENDIX

This appendix presents the results of the environmental sensitivity analysis prepared for the National Waterways Study Evaluation of Alternative Future Strategies for Action. Before the analysis itself is presented, the evolution of the approach used is discussed. In particular it is important to understand why this particular analysis was executed at all and why the issues addressed were treated as a sensitivity analysis.

Earlier in the development of the NWS workplan and in the development of the integration plan, additional scenarios and strategies were conceived which, had they been constructed, would have attempted to deal with various aspects of federal policy which impinge on the development of water resources. Environmental policy in particular was viewed as possibly affecting both the forecasts of water transportation use and the nature of strategies for action. After much discussion and internal review by the contractor team and Corps project staff several conclusions were reached. These were:

1. It was not possible to construct a meaningful forecast of the effects of environmental policy on the economy except in the area of coal use. The forecasts of water transportation of coal have in fact incorporated explicit assumptions about environmental aspects of coal use.

2. Strategies built around the idea of "reduced support for waterways" were excluded from further analysis by the Corps as being nonresponsive to NWS objectives. While the concept of "reduced support" which triggered this decision was concerned with funding levels, the notion of other adverse federal policies such as environmental policies was also included in "reduced support" or "less favorable" strategies.

Nevertheless, the study team believed that there was an adequate basis for concluding that environmental policy was important and could affect future management of the navigation system in two ways. These effects would possibly be felt through increased costs of actions and the possible prohibition of individual actions. Accordingly, it was decided to formulate and evaluate strategies, based

on existing environmental policies and treat the effects of different environmental policies as a sensitivity analysis. Thus, strategies were developed and evaluated based on the contractor's understanding of current environmental policies. The approach actually employed was to formulate strategies and actions without regard to potential environmental constraints and evaluate their effects. However, as an important part of the overall process of strategy development, explicit forecasts were made of future cost increases of dredging associated with existing practices geared to existing environmental policies. The procedure used for this forecast is described in Section IV of this report.

Thus, the sensitivity analysis to be conducted had to specify objectives, and include analysis of costs and analysis of individual actions. In order to accomplish this it was necessary to define the concepts of "more strict" and "less strict" environmental policies. This was based on a review of Element M (Analysis of Environmental Aspects of Waterways Navigation).

During the conduct of Element M several federal policies relating to the environment were reviewed and found to have various effects on the operation of the navigation system. The most important of these were:

1. Several laws impinging on dredging (Water Quality Act, Ocean Dumping Act, etc.).

2. Laws relating to the protection of wildlife (Fish and Wildlife Coordination Act, Endangered Species Act of 1973, etc.).

Thus the concepts of "more strict" and "less strict" are related to specific laws and policies, since these areas of environmental policy relate more strongly to management of the system. It should also be emphasized that environmental policy is not set by a single institution or focus of decision making. Rather, environmental policy evolves as the result of an ongoing process of interaction between legislation (statutes and budgets), private interests, federal executive agency decisions, other levels of government, and judicial proceedings. Thus while key attributes of "more strict" and "less

strict" policies that would affect waterways can be identified, the means by which these changes would occur cannot be specified and are beyond the scope of NWS. The key aspects of environmental policy included in this analysis are summarized in Table E-1.

Table E-1

Summary of Environmental Policy Assumptions

Regulations	Change	Implication for Waterways
	More Strict	
1977 Amendments to Clean Water Act	Open water disposal of dredged material in freshwater areas subject to same restrictions as ocean dumping.	Segments presently utilizing open water disposal will experience cost increases.
Endangered Species Act	Increased species lists and no waivers.	More mitigation will increase costs. Some actions may be precluded.
NPDES Permits	No waivers for dredging.	Increased costs for dredging.
	Less Strict	
Ocean Dumping Act	Modification or elimination of Bioassay procedures.	Greater flexibility in developing and maintaining the waterway system.
Endangered Species Act	Decreased species lists and more waivers.	Greater flexibility in developing and maintaining the waterway system.

Also, greater flexibility by states in permitting of dredging is assumed to reduce costs where current conditions are projected to increase costs.

To summarize, the principal effects of environmental policies incorporated into this appendix are the effects of policies on costs and whether or not particular actions could be executed at all. The remainder of this appendix presents the analysis of costs, executability of actions, and conclusions in turn.

ANALYSIS OF EFFECTS OF POLICIES ON COSTS

Of the four categories of costs considered in NWS integration (maintenance dredging, other operations and maintenance, rehabilitation, and construction) only dredging and construction were found to be significantly affected by environmental policies. These two categories are discussed in turn.

(a) Maintenance Dredging Costs

The impact of environmental policy on dredging is expected to be felt primarily in the different requirements for disposal of dredged material. The dredging cost forecasts for baseline environmental policy conditions displayed in Exhibit IV-8 incorporate substantial cost increases for some segments to meet baseline requirements. In fact, environmental requirements are the single most important factors influencing those forecasts in most segments.

The analysis of "more strict" and "less strict" policies is based in large part on the baseline forecast. In the case of "more strict" additional cost increases were forecast. In the case of "less strict", part or all of the increase in baseline costs was removed from the forecast. The results of the analysis for the baseline levels of dredging in the inventory are shown in Table E-2.

Table E-2 displays the baseline volume and unit cost for each segment from Appendix A. The growth rates for "more srict" and "less strict" are derived from the sensitivity cost forecast. The total cost under different conditions is then generated by equation E-1 below.

Table E-2

Sensitivity Analyses of Baseline Maintenance Dredging

Region (No.)	Segment (No.)	1977 Base Volume (100 c.y.)	1977 Unit Cost ($)	2003 Less Strict Growth Rate	2003 Total Cost (000's) Less Strict	2003 More Strict Growth Rate	2003 Total Cost (000's) More Strict
Upper Mississippi (1)	Upper Mississippi (1)	27,291	1.003	4.70	9,216	6.77	15,031
Lower Upper Mississippi (2)	Lower Upper Mississippi (2)						
	Middle Mississippi (3)	60,306	0.524	0.87	3,958	3.27	7,295
Lower Mississippi (3)	Lower Middle Mississippi (4)	220,000	0.263	0.91	7,323	2.98	12,415
	Upper Lower Mississippi (5)	109,211	0.232	0.91	3,207	2.98	5,537
	Lower Mississippi (6)	14,005	0.600	0.91	1,063	2.98	1,803
Baton Rouge to Gulf (4)	Baton Rouge to New Orleans (7)	58,446	0.342	0.40	2,264	2.64	3,936
	New Orleans to Gulf (8)	475,897	0.433	0.53	23,642	2.55	39,658
	Ouachita Black and Red Rivers (25)	24,494	0.519	1.64	1,940	3.05	3,395
	Old and Atchafalaya Rivers (26)	52,219	0.270	0.91	1,784	2.98	3,025
	GIWW Port Allen (27)	6,350	0.465	2.31	535	4.80	999
Illinois Waterway (5)	Illinois Waterway (9)	25,124	0.681	0.91	2,165	2.98	3,671
Missouri River (6)	Missouri River (10)	40,404	0.829	1.15	4,509	3.99	9,263
Ohio River (7)	Upper Ohio (11)	1,908	2.558	1.66	747	4.04	1,363
	Middle Ohio (12)	7,275	1.185	0.91	1,091	2.98	1,850
	Lower Ohio Three (13)	4,666	0.849	0.91	501	2.98	850
	Lower Ohio Two (14)	9,660	1.128	0.91	1,379	2.98	2,338
	Lower Ohio One (15)	20	1.000	0.91	3	2.98	4
	Monongahela River (16)	710	2.972	2.81	435	5.30	808
	Allegheny River (17)	400	2.775	2.81	228	5.30	425
	Kanawha River (18)	110	5.000	3.00	119	5.30	211
	Kentucky River (19)	1,110	1.082	0.91	151	2.98	255
	Green River (20)	750	1.293	0.91	123	2.98	208
	Cumberland (21)	892	2.029	2.81	372	5.30	693
Tennessee River (8)	Upper Tennessee (22)						
	Lower Tennessee (23)	300	1.733	0.91	66	2.98	112
Arkansas River (9)	Arkansas, Verdigris, White and Black (24)	32,942	0.735	2.84	5,015	5.05	8,716
Gulf Coast West (10)	GIWW West One (28)	41,567	0.701	1.38	4,161	3.34	6,846
	GIWW West Two (29)	430,132	0.314	1.40	19,387	2.80	27,692
	GIWW West Three (30)	50,575	1.066	1.36	7,660	3.36	12,731
	Houston Ship Channel (34)	87,460	0.535	2.84	9,691	5.12	17,126

Table E-2 (Continued)

Sensitivity Analyses of Baseline Maintenance Dredging

Region (No.)	Segment (No.)	1977 Base Volume (100 c.y.)	1977 Unit Cost ($)	2003 Less Strict Growth Rate	2003 Total Cost (000's) Less Strict	2003 More Strict Growth Rate	2003 Total Cost (000's) More Strict
Gulf Coast East (11)	GIWW East One (31)	45,670	0.521	0.62	2,794	2.77	4,842
	Mobile to St. Marks (32)	17,304	0.751	2.05	2,203	4.06	3,657
	Florida Gulf Coast (33)	16,580	2.025	0.89	4,227	2.98	7,204
	Apalachicola, Chattahoochee and Flint River (38)	17,015	0.746	1.53	1,884	3.73	3,289
Mobile River and Tributaries (12)	Black Warrior Mobile (35)	63,843	0.515	3.87	8,824	5.92	14,667
	Alabama-Coosa Rivers (36)	16,344	0.386	1.46	928	3.59	1,578
	Tennessee-Tombigbee (37)						
South Atlantic Coast (13)	Florida-Georgia Coast (39)	119,795	0.819	1.68	15,130	3.63	24,794
	Carolinas Coast (40)	167,628	0.939	1.88	25,546	4.14	45,193
Middle Atlantic Coast (14)	Chesapeake and Delaware Bays (41)	58,937	2.018	2.69	23,716	4.98	42,000
	New Jersey-New York Coast (42)	57,689	2.061	-0.09	11,615	1.34	16,806
North Atlantic Coast (15)	Upper Atlantic (44)	8,221	3.050	1.37	3,572	3.65	6,368
Great Lakes/ St. Lawrence Seaway (16)	New York State Waterways (43)						
	St. Lawrence Seaway (45)	4,263	1.208	0.91	652	2.98	1,105
	Lake Erie (46)	42,920	1.375	1.72	9,194	4.16	17,029
	Lake Huron (47)	7,164	7.581	2.36	9,960	4.88	18,745
	Lake Michigan (48)	13,443	2.067	1.72	4,329	4.08	7,859
	Lake Superior (49)	2,308	2.409	2.07	947	4.54	1,764
Washington-Oregon Coast (17)	Puget Sound (50)	6,040	1.250	1.92	1,238	4.21	2,206
	Oregon-Washington Coast (53)	61,802	0.805	0.02	5,001	1.90	8,116
Columbia-Snake Waterway (18)	Upper Columbia-Snake Waterway (51)						
	Lower Columbia-Snake Waterway (52)	199,915	0.378	-0.06	7,440	2.64	14,879
California Coast (19)	Northern California (54)	4,748	1.264	-0.03	555	1.27	833
	San Francisco Bay (55)	59,439	1.630	3.59	24,239	5.59	39,852
	Central South California (56)	101,063	1.817	0.79	22,532	1.42	26,495
Alaska (20)	Southeast Alaska (57)						
	South Central Alaska (58)	825	2.994	0.91	313	2.98	526
	West and North Coasts of Alaska (59)	110	4.545	3.51	123	5.89	221
Hawaii and Pacific Territories (21)	Western Pacific (60)	1,518	1.357	0.12	213	1.58	310
Caribbean	Caribbean (61)	2,050	1.410	0.12	298	1.58	434
TOTALS					300,200		499,008

$$\text{Cost in 2003} = \text{Volume} \times \text{Unit Cost} \times (1 + \text{growth factor})^{26} \qquad \text{E-1}$$

For example, the projected cost under "more strict" policies for Segment One are computed as follows.

$$\$15,031,444 = (27,291 \times 100) \times 1.003 \times (1.068)^{26}$$

The total dredging cost in 2003 for the entire 1978 baseline system under "less strict" policies and "more strict" policies in approximately $300 million and $500 million respectively, compared to approximately $360 million for the present system (including projects under contruction) under baseline policies. Table E-3 shows the sensitivity analysis applied to the maintenance dredge volume reductions incorporated into Strategy II and the maintenance dredging volumes increments incorporated into Strategy IV.

As can be seen ιrom Table E-3, the application of different environmental policy assumptions creates a wide spread in the future maintenance dredging cost changes associated with Strategies II and IV respectively.

(b) <u>Construction Costs</u>

1. <u>Construction Dredging for Channel Deepening</u>. Strategy IV incorporated several actions to provide deeper channels on various shallow draft inland waterways and at selected coastal ports. The same environmental considerations apply to the cost of one-time dredging for channel deepening as apply to channel maintenance. However, since this dredging was not priced in the base data in the same manner as the NWS inventory maintenance dredging, the sensitivity analysis of these first cost was performed by applying rough adjustments to the total costs of channel deepening (exclusive of concommitant lock construction). The results are shown in Table E-4.

Several aspects of the results shown in Table E-4 need to be pointed out. First of all, the basic cost being escalated is for dredging only, based upon available data. Second, in the projection of costs for Strategy IV in Section V, dredging costs for these actions were not

Table E-3

Sensitivity Analysis of Changes in Dredge Volumes

Region	Segment	Decrease in Volume (100 c.y.)	Cost Savings: Less Strict ($1,000)	Cost Savings: More Strict ($1,000)	Increase in Volume (100 c.y.)	Cost Increases: Less Strict ($1,000)	Cost Increases: More Strict ($1,000)
1. Upper Mississippi	1. Upper Mississippi, Minneapolis to Illinois River	1,065	360	587	152,152	51,303	83,003
2. Lower Upper Mississippi	3. Middle Mississippi, Missouri River to Ohio River	2,426	159	293	152,500	10,010	18,447
4. Baton Rouge to Gulf	8. Mississippi River New Orleans to Gulf				606,000	30,106	50,500
5. Illinois River	9. Illinois River				50,000	4,309	7,306
6. Missouri River	10. Missouri River	3,573	399	819			
7. Ohio River	11. Upper Ohio, Confluence of Allegheny and Monongahela to Kanawha River	108	42	77			
	12. Middle Ohio, Kanawha River to Kentucky River	3,265	490	830			
	18. Kanawha River	14	15	27			
	21. Cumberland River				6,000	2,502	4,662
8. Tennessee River	23. Lower Tennessee, Junction with Tennessee Tombigbee to Mouth				1,950	428	725
9. Arkansas River	24. Arkansas Verdigris, White and Black Rivers	8,061	1,227	2,133			
10. Gulf Coast West	27. GIWW West One, New Orleans to Calcasieu River	21,911	2,194	3,609	2,914	292	480
	29. GIWW West Two, Calcasieu River to Corpus Christi	26,482	1,194	1,705	40,000	1,803	2,575
	30. GIWW West Three, Corpus Christi to Brownsville	12,290	1,861	3,094			
	34. Houston Ship Channel	10,760	1,192	2,109			

Table E-3 (Continued)

Sensitivity Analysis of Changes in Dredge Volumes

Region	Segment	Decrease in Volume (100 c.y.)	Cost Savings Less Strict ($1,000)	Cost Savings More Strict ($1,000)	Increase in Volume (100 c.y.)	Cost Increases Less Strict ($1,000)	Cost Increases More Strict ($1,000)
11. Gulf Coast East	31. GIWW East One, New Orleans to Mobile	5,206	319	552	35,390	2,165	3,752
	32. Mobile to St. Marks, Florida	5,733	730	1,212	32,410	4,125	6,850
12. Mobile River and Tributaries	35. Black Warrior-Mobile Harbor	1,693	234	389	29,300	4,050	6,731
13. South Atlantic Coast	39. Florida-Georgia Coast	34,814	4,296	7,040	22,983	2,983	4,757
	40. Carolinas Coast				16,050	2,294	4,050
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	4,971	2,000	3,549	68,365	27,518	48,812
	42. New Jersey-New York Coast	26,558	5,347	7,737	22,290	4,400	6,494
15. North Atlantic Coast	44. Upper Atlantic, New York-Connecticut Boundary to St. Croix River, Maine	3,671	1,595	2,844			
16. Great Lakes, St. Lawrence Seaway	45. Lake Ontario and St. Lawrence Seaway	3,132	479	812	2,000	306	518
	46. Lake Erie	4,042	866	1,604	350	75	139
	47. Lake Huron	1,200	1,668	3,140			
	48. Lake Michigan	5,642	1,817	3,299	5,200	1,675	3,040
	49. Lake Superior	544	233	416	392	161	300
17. Washington-Oregon Coast	50. Puget Sound	860	176	314	2,000	410	730
	53. Oregon-Washington Coast	17,589	1,423	2,310	8,560	693	1,124
18. Columbia-Snake Waterway	52. Lower Columbia-Snake Waterway	65,599	2,441	4,882	2,500	93	186
19. California Coast	54. Northern California	1,350	158	237			
	55. San Francisco Bay	2,177	888	1,460			
	56. Central-South California	30,543	6,810	8,007			
TOTAL			40,633	65,087		151,781	255,989

Table E-4

Sensitivity Analysis of Construction Dredging Costs

Region	Segment	Action	Baseline First Cost for Dredging ($1,000)	Less Strict Growth Rate	Less Strict Cost ($1,000)(1)	More Strict Growth Rate	More Strict Cost ($1,000)(1)	Baseline Growth Rate	Baseline Cost ($1,000)(1)
1. Upper Mississippi	1. Upper Mississippi	Deepen to 10'	15,000	4.70	27,524	6.77	35,150	5.08	31,526
4. Baton Rouge to Gulf	7. Baton Rouge New Orleans	Deepen to 55'	150,000	0.40	159,634	2.64	210,470	0.73	164,075
	8. New Orleans to Gulf	Deepen to 55'	80,000	0.53	85,691	2.55	110,902	0.73	87,934
5. Illinois Waterway	9. Illinois Waterway	Deepen to 12"	174,000	0.91	195,746	2.98	254,001	1.15	201,806
7. Ohio River	10. through 15 (Main Stem of Ohio River)	Deepen to 12'	100,000	1.15	116,026	3.99	166,299	1.15	116,026
10. Gulf Coast West	29. GIWW West Two	Deepen Galveston to 50'	100,000	1.40	119,010	2.80	143,109	1.64	123,549
12. Mobile River and Tributaries	35. Black Warrior-Mobile Harbor	Deepen Mobile to 55'	300,000	3.07	491,465	5.92	633,629	4.76	549,114
14. Middle Atlantic Coast	41. Chesapeake and Delaware Bays	Deepen Norfolk/Hampton Roads to 55'	170,000	2.69	240,057	4.98	319,767	3.68	271,947
		Deepen Baltimore to 55'	215,000	2.69	303,602	4.98	404,912	3.68	343,933
TOTAL			1,304,000		1,739,555		2,270,707		1,890,790

NOTE: [1] 1990 cost.

isolated from other construction costs. Rather, they were treated as general construction costs and escalated at a rate of 1.25% per year in all segments. For this reason, the base year costs shown in Table E-4 are also shown escalated at the baseline compound rates used for maintenance dredging. Finally, all these costs are escalated only to the year 1990, the year in which these actions are assumed to become operational for Strategy IV. As can be seen from Table E-4, "more strict" policies would add almost $400 million to the first costs of Strategy IV. "Less Strict" policies would reduce these costs by about $150 million.

2. Lock Construction Actions. After the channel deepening actions, major structural actions to expand capacity at locks are the most costly construction actions incorporated into any strategy. A review of available precedents indicated that the impact of environmental policies on lock construction actions fall in three main areas. These are excavation, dewatering and environmental analyses. Based on the experience of the John H. Overton Lock and Dam project, it was found that these three activities collectively account for a small part of total project costs. "Less strict" policies would have negligible effects on these costs. "More strict" policies could have substantial effects on each of these three items, but the effect on total project costs would be about a 12% increase in first costs for construction. This was not deemed to be of sufficient magnitude to merit further pursuit. This does not account for fundamental design changes and associated costs incorporated into projects to address environmental concerns. However, these cost impacts are site specific and beyond the scope of this analysis.

3. Costs Associated with Delays. Environmental disputes also have delayed the completion of major projects, particularly electrical generating stations, in the United States in recent years. However, a review of such incidents of apparent delays did not reveal cost increases that were attributable to environmental policies alone.

Delays in construction schedules do impose additional costs in financial carrying charges. However, since these were not incorporated into any of the cost projections for baseline construction periods, it was not considered appropriate to include them in this sensitivity analysis either.

ANALYSIS OF EFFECTS OF POLICIES ON ACTIONS

The impact of "more strict" and "less strict" policies on the ability to implement individual actions is necessarily judgmental. While it is true that the evolution of the baseline environmental policies assumed for NWS during the decade of the 1970's resulted in some projects being stopped or abandoned (e.g., the Cross Florida Barge Canal), it is impossible to identify rigorously a single threshold of adverse decisions for individual projects, much less identify patterns that yield this result. It is important to remember that there are many actors in these processes. Decisions are sometimes taken by proponents to abandon projects more out of exhaustion than as a result of clearcut decisions that specific actions would be prohibited (e.g., the decision in 1978 by SOHIO Oil Co. to abandon its plan for a terminal and connecting pipeline at Long Beach California to receive Alaskan crude oil). Thus any statement about the implementability of actions under "more strict" and "less strict" policies can only be stated in generalized terms of probabilities.

(a) Maintenance Dredging

In general, it is not expected that either "more strict" or "less strict" policies will have any measurable affect on the ability to perform maintenance dredging. Costs will be affected and these have been analyzed earlier. Maintenance dredging of individual projects may be delayed, reduced, or deferred based on site specific considerations. No general rule that would allow rigorous generalizations across segments and regions can be derived from the available data beyond the expectation that, given the ability to absorb greater costs, dredging will probably be allowed to continue.

(b) Lock Construction

In general, lock construction activities are likely to occur under baseline policies. Controversies will arise around actions on the Upper Mississippi above Cairo and the Illinois Waterway, and some actions in these areas may be prohibited under baseline policies. Under "more strict"

policies all lock construction actions in all regions may be prohibited. Under "less strict" policies all lock construction actions would probably be permitted. The one major policy which could be of great importance in affecting these actions is the level of enforcement of the Endangered Species Act. Given enough time and money some unique species can almost always be found that, under a strict interpretation, could be affected (if only indirectly) by additional lock capacity. Thus strict expansion of species lists, strict interpretation of effects, and no waivers could limit these actions.

(c) Channel and Port Deepening

The same considerations affecting the likelihood of lock construction also influence the likelihood of channel deepening, only more so. Very few deepening actions would likely be permitted under more strict policies. Most actions would probably be permitted under "less strict" policies.

Besides the Endangered Species Act, laws dealing with water quality also would be important to these actions. Where port deepening in particular would disturb polluted sediments that contain toxic substances, such actions would be difficult to implement under baseline policies. Port deepening in such cases would likely be prohibited under "more strict" policies.

CONCLUSIONS

Several conclusions result from the analysis of this appendix. These are:

1. Environmental policies will have more direct effects on the cost of dredging than on the cost of other actions.

2. Baseline environmental policies and less strict policies will generally allow most actions to take place, with the probable exception of some deepening actions.

3. More strict environmental policies will allow operations and maintenance of the present system, but will curtail other actions.

4. Strategies I and II would be strongly affected by future environmental policies. The higher costs imposed by more strict policies will cause these strategies to fail to meet basic needs of the system under the postulated real budget constraint earlier then under baseline policies. Conversely, less strict policies will postpone the day of reckoning. Strategy II in particular will find it possible to meet most of the needs of the "A" and "B" system and avoid withdrawal of federal support from the higher ranked "C" Segments under some scenarios under "less strict" policies

5. Strategy IV will be strongly affected by future environmental policies. Only under a less strict set of policies would it become likely that all the channel and port deepening actions included in Strategy IV be likely to be implemented.

☆ U.S. GOVERNMENT PRINTING OFFICE : 1982 O - 374-802

THIS REPORT IS PART OF THE NATIONAL WATERWAYS STUDY AUTHORIZED BY CONGRESS IN SECTION 158 OF THE WATER RESOURCES DEVELOPMENT ACT OF 1976 (PUBLIC LAW 94-587). THE STUDY WAS CONDUCTED BY THE US ARMY ENGINEER INSTITUTE FOR WATER RESOURCES FOR THE CHIEF OF ENGINEERS ACTING FOR THE SECRETARY OF THE ARMY.

FILM